POL-1017

DEPARTMENT OF ECOLOGY WATER RESOURCES PROGRAM
POLICY AND INTERPRETIVE STATEMENT

COLLECTION OF RAINWATER FOR BENEFICIAL USE

Effective Date:	10/09/2009
Contact:	Policy and Planning Section
References:	*Statute:* Chapters 90.03 and 90.54 RCW
Purpose:	To (1) clarify that a water right is not required for on-site storage and use of rooftop or guzzler collected rainwater, and (2) identify the Department of Ecology's intent to regulate the storage and use of rooftop or guzzler collected rainwater if and when the cumulative impact of such rainwater harvesting is likely to negatively affect instream values or existing water rights.
Application:	This Interpretive Statement applies to the water right permit requirement in RCW 90.03 and the authority to regulate rainwater harvesting systems.

This policy supersedes any previous policy statement with which it conflicts.

The on-site storage and/or beneficial use of rooftop or guzzler collected rainwater is not subject to the permit process of RCW 90.03. If and when the department determines that rooftop or guzzler rainwater harvesting systems are likely to negatively affect instream values or existing water rights, local restrictions may be set in place to govern subsequent new systems. To qualify as rooftop collected rainwater, the roof collecting the rainwater must be part of a fixed structure above the ground with a primary purpose other than the collection of rainwater for beneficial use. A guzzler is a device used to catch and store rainwater to provide drinking water for wildlife, livestock or birds.

Jay J. Manning, Director
Department of Ecology

Note: These policies and procedures are used to guide and ensure consistency among water resources program staff in the administration of laws and regulations. These policies and procedures are not formal administrative regulations that have been adopted through a rule-making process. In some cases, the policies may not reflect subsequent changes in statutory law or judicial findings, but they are indicative of the department's practices and interpretations of laws and regulations at the time they are adopted. If you have any questions regarding a policy or procedure, please contact the department.

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ASPE American Society of Plumbing Engineers™

ARCSA American Rainwater Catchment Systems Association

PLUMBING ENGINEERING & DESIGN STANDARD

ARCSA/ASPE/ANSI 63-2020: Rainwater Catchment Systems

Approved American National Standard ANSI

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This edition of the ARCSA/ASPE Rainwater Catchment Systems Plumbing Engineering and Design Standard was prepared by ASPE Working Group 63 — Rainwater Catchment Systems. The list below represents the committee membership at the time the final text of this standard was balloted.

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FORWARD (INFORMATIVE)

This Rainwater Catchment System Design and Installation Standard (hereinafter referred to as the Standard) has been developed by a joint effort of the American Rainwater Catchment Systems Association (ARCSA) and the American Society of Plumbing Engineers (ASPE). The purpose of this Standard is to assist engineers, designers, plumbers, builders/developers, local government, and end users in safely implementing a rainwater catchment system. This Standard is intended to apply to new rainwater catchment installations, as well as alterations, additions, maintenance, and repairs to existing installations.

This Standard is intended to be consistent with, and complimentary to, nationally adopted codes and regulations. However, designers/installers are advised to consult with the plumbing authority having jurisdiction regarding local conditions, requirements, and restrictions.

This Standard is not intended to cover all of the requirements for the design and installation of rainwater catchment systems. The requirements set in this Standard are intended to be minimum requirements. The user of this Standard is advised to check with the authority having jurisdiction to determine if additional requirements may apply. As an example, this Standard does not include detailed information related to how to ensure proper backflow prevention. The local building/plumbing codes should be consulted to ensure that all appropriate backflow protection requirement are met. In addition, some potable water systems may be required to meet applicable federal, state, and/or tribal agency requirements set forth to enforce the Safe Drinking Water Act. The authority having jurisdiction in enforcing the requirements must be consulted prior to initiating the design of a system.

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ARCSA/ASPE/ANSI 63-2020: RAINWATER CATCHMENT SYSTEMS (NORMATIVE)

1.0 GENERAL

1.1 Scope

1.1.1 The scope of this Standard covers rainwater catchment systems that utilize the principle of collecting and using precipitation from a rooftop and other hard, impervious surfaces. This Standard does not apply to the collection of rainwater from vehicular parking or other similar surfaces.

1.2 Performance Objectives

1.2.1 The objectives of this Standard are to provide guidance in how to provide and maintain a safe alternative to utility-provided water and/or well water and to optimize rainwater utilization, while ensuring:

a. Reduction of risk to consumers from poor design, installation, maintenance, or illegal work.

b. Reduction of risk to the public from injury or loss of amenity due to a failure of the supply, installation, maintenance, or operation of the rainwater catchment system.

c. The rainwater catchment system will assist in maintaining and enhancing the quality of the environment while helping to ensure compliance with the intent of relevant regulations and government officials.

d. Reduction of the use or need of municipal potable or private well water systems.

1.3 Units of Measurement

1.3.1 Values are stated in the International System of Units (SI) with U.S. Customary Units being referenced parenthetically. The SI units shall be considered as the standard.

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2.0 REFERENCED STANDARDS

The standards referenced in this section are considered normative either by direct reference in this Standard or through a general reference of this Section in the Standard.[1]

2.1 American Society of Mechanical Engineers (ASME)

2.1.1 ASME A112.6.4-2003: Roof, Deck, and Balcony Drains

2.2 American Public Health Association, American Water Works Association, Water Environment Federation

2.2.1 Standard Methods for the Examination of Water and Wastewater, 22nd Edition

2.3 ASTM International

2.3.1 ASTM B32-08: Standard Specification for Solder Metal

2.3.2 ASTM B75/B75M-11: Standard Specifications for Seamless Copper Tube

2.3.3 ASTM B828-02 (2010): Standard Practice for Making Capillary Joints by Soldering of Copper and Copper Alloy Tube and Fittings

2.3.4 ASTM D1785-12: Standard Specification for Poly(Vinyl Chloride) (PVC) Plastic Pipe, Schedules 40, 80, and 120

2.3.5 ASTM D2241-09: Standard Specification for Poly(Vinyl Chloride) (PVC) Pressure Rated Pipe (SDR Series)

2.3.6 ASTM D2466-06: Standard Specification for Poly(Vinyl Chloride) (PVC) Plastic Pipe Fittings, Schedule 40

2.3.7 ASTM D2467-06: Standard Specification for Poly(Vinyl Chloride) (PVC) Plastic Pipe Fittings, Schedule 80

2.3.8 ASTM D2657-07: Standard Practice for Heat Fusion Joining of Polyolefin Pipe and Fittings

2.3.9 ASTM D2661-11: Standard Specification for Acrylonitrile-Butadiene-Styrene (ABS) Schedule 40 Plastic Drain, Waste, and Vent Pipe and Fittings

2.3.10 ASTM D2665-12: Standard Specification for Poly(Vinyl Chloride) (PVC) Plastic Drain, Waste, and Vent Pipe and Fittings

2.3.11 ASTM D2855-10: Standard Practice for Making Solvent-Cemented Joints with Poly(Vinyl Chloride) (PVC) Pipe and Fittings

2.3.12 ASTM D2949-10: Standard Specification for 3.25-in. Outside Diameter Poly(Vinyl Chloride) (PVC) Plastic Drain, Waste, and Vent Pipe and Fittings

2.3.13 ASTM D3261-10a: Standard Specification for Butt Heat Fusion Polyethylene (PE) Plastic Fittings for Polyethylene (PE) Plastic Pipe and Tubing

2.3.14 ASTM D3311-11: Standard Specification for Drain, Waste, and Vent (DWV) Plastic Fittings Patterns

2.3.15 ASTM D3350-12: Standard Specification for Polyethylene Plastics Pipe and Fittings Materials

2.3.16 ASTM F628-08: Standard Specification for Acrylonitrile-Butadiene-Styrene (ABS) Schedule 40 Plastic Drain, Waste, and Vent Pipe With a Cellular Core

2.3.17 ASTM F714-12e1: Standard Specification for Polyethylene (PE) Plastic Pipe (DR-PR) Based on Outside Diameter

[1] Additional standard and guidance document references have been provided in Appendix A for informational purposes.

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2.3.18 ASTM F1866-07: Standard Specification for Poly(Vinyl Chloride) (PVC) Plastic Schedule 40 Drainage and DWV Fabricated Fittings

2.3.19 ASTM F1901-10: Standard Specification for Polyethylene (PE) Pipe and Fittings for Roof Drain Systems

2.4 American Water Works Association (AWWA)

2.4.1 ANSI/AWWA C110/A21.10-2012: Standard for Ductile-Iron and Gray-Iron Fittings

2.4.2 AWWA C606-2011: Standard for Grooved and Shoulder Joints

2.5 Cast Iron Soil Pipe Institute (CISPI)

2.5.1 CISPI 301-09: Standard Specification for Hubless Cast Iron Soil Pipe and Fittings for Sanitary and Storm Drain, Waste, and Vent Piping Applications

2.5.2 CISPI 310-11: Standard Specification for Couplings for Use in Connection With Hubless Cast Iron Soil Pipe and Fittings for Sanitary and Storm Drain, Waste, and Vent Piping Applications

2.6 International Organization for Standardization (ISO)

2.6.1 ISO/IEC 17065-2012: Conformity Assessment—Requirements for Bodies Certifying Products, Processes and Services

2.6.2 ISO/IEC 17011-2004: Conformity Assessment—General Requirements for Accreditation Bodies Accrediting Conformity Assessment Bodies

2.7 NSF International

2.7.1 NSF Protocol P151: Health Effects from Rainwater Catchment System Components

2.7.2 NSF/ANSI Standard 14-2011: Plastic Piping System Components and Related Materials

2.7.3 NSF/ANSI Standard 42-2010: Drinking Water Treatment Units—Aesthetic Effects

2.7.4 NSF/ANSI Standard 53-2010: Drinking Water Treatment Units—Health Effects

2.7.5 NSF/ANSI Standard 55-2009: Ultraviolet Microbiological Water Treatment Systems

2.7.6 NSF/ANSI Standard 58-2009: Reverse Osmosis Drinking Water Treatment Systems

2.7.7 NSF/ANSI Standard 60-2011: Drinking Water Treatment Chemicals—Health Effects

2.7.8 NSF/ANSI Standard 61-2011: Drinking Water System Components—Health Effects

2.8 U.S. Department of Labor, Occupational Safety & Health Administration (OSHA)

2.8.1 Standard 1926: Safety and Health Regulations for Construction, Subpart P, Excavations

2.8.2 OSHA Regulations for Confined Space Entry, 29 CFR 1910

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3.0 DEFINITIONS

The following terms are defined in the manner in which they are intended to be used in the Standard. Additional definitions of terms relevant to the scope of the Standard that are not used in the body of the Standard are provided in Appendix C for informational purposes.

3.1 Accredited

Verification that a certification body meets the requirements of ISO/IEC 17065 by a third-party agency operating in compliance with ISO/IEC 17011.

3.2 Certified

Verified compliance to a standard by a certification body that has been accredited by a third-party as having systems in compliance with ISO/IEC 17065.

3.3 Cistern

The central storage component of the rainwater harvesting system. Also referred to as a storage tank.

3.4 Code

Refers to the local written authority.

3.5 Debris Excluder

A screen or other device installed on the gutter or downspout system to prevent the accumulation of leaves, needles, or other debris in the system.

3.6 Disinfection

Reduction of viable microorganisms to a level that is deemed suitable for the intended application. Typical units of measure are colony forming units per milliliter (cfu/ml).

3.7 Filtration

Physical removal of liquid-borne contaminants by means of separation from the output flow.

3.7.1 Particulate Filtration: Removal of suspended particles (measured in units of total suspended solids [TSS]).

3.7.2 Carbon/Adsorption Filtration: Removal of dissolved compounds.

3.8 First Flush

A method for the removal of sediment and debris from the collection surface by diverting initial rainfall volume from entry into the cistern(s).

3.9 Flat

Having a slope no greater than 1 in 50.

3.10 Groundwater

Water that has saturated into the ground and no longer flows across the surface.

3.11 Piping System

Pipes and components that distribute water to various fixtures and devices.

3.12 Point of Use

A point in a domestic water system, nearest to a water-consuming plumbing fixture, where water is used.

3.13 Precipitation

Water that has precipitated from the atmosphere (e.g., rain, snow, mist, dew).

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3.14 Private Water System

System used by less than 25 persons over a 60-day period, or containing fewer than 15 plumbing fixtures.

3.15 Process Water

Water to be used for household and commercial applications.

3.16 Public System

System used by 25 persons or more over a 60-day period, or containing 15 service connections or more.

Note: The definition of public system may vary depending on the state agency having jurisdiction over the enforcement of the Safe Drinking Water Act. This definition is based on the Safe Drinking Water Act; however, the user of this Standard is advised to check with the state or tribal agency having jurisdiction to determine the definition for public system that may apply to the location of the system installation.

3.17 Quiescent Flow

Routing of rainwater into rainwater reservoirs so that the existing sediment is not disturbed in the rainwater reservoir and an immediate settling of solids is possible.

3.18 Rainwater

Water from natural precipitation that is not contaminated by use.

3.19 Rainwater Harvesting System

Water system for collecting and utilizing rainwater, consisting of a cistern(s), pipe, fittings, pumps, and/or other plumbing appurtenances, required for and/or used to harvest and distribute rainwater. Also called a rainwater catchment system or rainwater collection system.

3.20 Return Bend Elbow

A section of pipe with a 180-degree bend.

3.21 Roof Drainage System

A system, comprised of roof drains, scuppers, gutters, and downspouts, used to convey the rainwater from the roof surface to the roof washer and the cistern. Also called a conveyance system.

3.22 Roof Wash or Roof Washer

A device or method for the removal of sediment and debris from the collection surface by diverting initial rainfall from entry into the cistern(s). Also called a first flush device.

3.23 Screen

A filtration device, constructed of corrosion-resistant wire or other approved mesh, having openings in determined sizes.

3.24 Sedimentation

Separation of solids from the water via gravity.

3.25 Slope or Sloping

Having a slope greater than 1 in 50.

3.26 Stormwater

Natural precipitation that has contacted a surface at grade or below grade and has not been put to beneficial use.

3.27 Stormwater Catchment System

A system that collects and stores stormwater for beneficial use. Also called a stormwater harvesting system.

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3.28 Suction Line

Water pump inlet piping.

3.29 Sun Barrier

A cover, or erected structure, specifically to shelter a cistern from the direct rays of the sun.

3.30 Surface Irrigation

Water that is applied above ground level and is directly exposed to the aboveground surface and/or air.

3.31 Subsurface Irrigation

Irrigation system installed below finished grade within the topsoil.

3.32 Surface Water

Rainwater that touches the ground and flows across the surface of the ground (landscapes, driveways, roadway, parking surface, gully, creeks, streams, etc.). Also called stormwater.

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4.0 DESIGN AND INSTALLATION REQUIREMENTS

4.1 Collection Parameters

4.1.1 All piping and plumbing system materials and components used in the installation of a rainwater catchment system shall comply with the applicable referenced standards specified in Section 2 and be approved for the specific use per local plumbing code, or be listed for the applicable use.

a. Collection roofing, gutters, piping, fittings, valves, screens, downspouts, leaders, flushing devices, tanks, and liners shall be approved for the intended use.

b. All tank interior surfaces and equipment shall be washed clean before they are put into service.

c. For systems intended for non-potable applications and having storage volumes totaling less than 1,363 liters (360 gallons), no treatment is required.

d. Water level control devices that control pumps, makeup water valves, etc., in contact with the water supply shall be mercury-free devices.

e. The system shall be located and maintained to minimize or prevent overhanging vegetation and airborne pollution from contaminating collected rainwater.

4.1.2 For non-potable water applications:

a. The collection surface shall be constructed of aboveground, hard-surface, impervious material.

b. Harvested rainwater shall be filtered or treated to an appropriate quality suitable for the intended use. The local authority having jurisdiction should be consulted regarding the required water quality.

c. Collection of water from vehicular parking surfaces or other similar surfaces shall be compliant with the latest version of ARCSA/ASPE/ANSI 78: Stormwater Harvesting System Design for Direct End-Use Applications.

4.1.3 The collection surfaces for potable water applications shall comply with 4.9.1 and 4.9.2 of this Standard.

4.2 Conveyance System

4.2.1 The roof drainage system used to collect rainwater shall comply with the following:

a. All piping, plumbing components, and materials used shall be manufactured of a material approved for the intended application, conforming to the standards described herein in Section 2.

b. The conveyance systems leading to the cistern shall be fitted with a pre-filtration device (e.g., debris excluder or equivalent device) to prevent the accumulation of leaves, needles, or other debris in the cistern.

4.3 Pre-filtration

4.3.1 All rainwater shall pass through a pre-filtration system before entering the cistern(s).

a. The pre-filter shall be provided with a debris screen that protects the cistern from the intrusion of debris, insects, vermin, or other organisms that can be a potential danger if allowed to enter a cistern. The debris screen shall be corrosion resistant and shall have openings no larger than a nominal 0.15 cm (1,500 microns) (1/16 in.) or have been certified by a government regulatory agency to remove particles greater than 500 µm.

Exception: Pre-filters with a self-cleaning design are not required to have the aforementioned debris screen.

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b. If more than one cistern is used, a pre-filtration system shall be provided for each cistern.

Exception: Where cisterns are interconnected to supply water in series, a single pre-filter is permitted.

c. Pre-filtration screens or filters shall be readily accessible for regular maintenance and be maintained consistent with the manufacturer's specifications.

4.3.2 First-flush devices are optionally used to wash accumulated debris from the collection surface before rainwater is allowed to enter the storage tank. When first-flush devices are used, these systems shall meet the following design requirements:

a. If used, first-flush devices shall be placed before pre-filtration or have pre-filtration integral to the design.

b. The approximate amount of rainfall to be diverted shall be adjustable as necessary to minimize cistern water contamination. (See Appendix B: Example Piping Schematics for guidance in determining the pre-wash water volume.)

c. Water containing impurities drained from the first-flush device shall be piped away from the storage tank and terminate in a location so as not to cause damage to property or cause erosion.

d. First-flush devices shall be provided with an automatic means of self-draining between rain events and will be checked for proper drainage after each rain event.

e. First-flush devices shall be readily accessible for regular maintenance.

4.4 Cisterns / Storage

4.4.1 The following are the minimum requirements for cisterns. Additional requirements are provided in Section 4.9 for potable water applications.

4.4.2 General

a. Cisterns may be used as rainwater collection points for stormwater/rainwater retention and/or to provide a reservoir for later use. All rigid-bodied cisterns and all cisterns over 1.22 m (4 ft) in height (rigid or flexible) shall have access to allow inspection and cleaning.

4.4.3 Installation

a. Cisterns may be installed either above- or below-grade.

b. Cisterns shall comply with the administrative authority having jurisdiction, local building codes and ordinances, and/or as certified by a structural engineer.

c. Above-grade plastic tanks used as cisterns shall be listed for the applicable use for the intended application.

d. Above-grade cisterns shall be protected from direct sunlight or shall:

(1) Be constructed using opaque, UV-resistant materials (i.e., heavily tinted flexible or rigid plastic, metal tank with lining, concrete, etc.), or

(2) Have specially constructed sun barriers (e.g., installed in garages, crawlspaces, sheds, etc.) to minimize heat gain of the stored water.

e. Below-grade cisterns, located outside a building, shall be provided with manhole risers a minimum of 10.2 cm (4 in.) above the surrounding grade and/or installed in such a way as to prevent surface- or groundwater from entering the cistern.

(1) Manholes shall be designed in accordance with OSHA Regulations for Confined Space Entry, 29 CFR 1910.

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(2) Cisterns installed beneath a building structure likewise shall be installed in such a way as to prevent surface or groundwater from entering through the top of any fittings.

f. Where the installation requires a foundation, the foundation shall be flat and shall be designed to support the cistern's weight when the cistern is full, consistent with the bearing capability of adjacent soil.

g. In areas where sustained freezing temperatures occur, provisions shall be made to keep the cistern and the related piping from freezing.

h. All cisterns shall be installed in accordance with the manufacturer's installation instructions.

(1) Underground tanks shall be installed in compliance with OSHA Standard 1926 Subpart P, fall protection rules and regulations, and any local codes relating to excavation and backfill technique or safety.

(2) Above-grade tanks shall be installed on a sturdy and level foundation or platform, adequately secured, with adequate drainage consistent with local codes, ordinances, and seismic regulations.

(3) All water storage tanks requiring field erection must be built/installed by trained personnel.

i. In a situation where the soil can become saturated, underground tanks shall be ballasted, or otherwise secured, to prevent the tank from floating out of the ground when empty. The combined weight of the tank and hold-down ballast shall meet or exceed the buoyancy force of the tank.

j. Cisterns shall be provided with a means for draining and cleaning. Where gravity drainage is not possible, a provision for pumping water from the tank shall be provided.

k. All cistern openings shall be protected from vermin entry, unintentional entry by humans, or tampering.

(1) Where an opening is provided that could allow the entry of personnel, the opening shall be marked "DANGER — CONFINED SPACE".

4.4.4 Inlets, Outlets, and Openings

a. Cistern inlets shall be installed such that they introduce water to the tank with little to no turbulence.

b. The overflow outlet, or flap valve, shall be protected with a screen having openings no greater than 1.5 mm (0.06 in.), or as otherwise appropriate, for preventing the entrance of insects or vermin into the cistern.

(1) The overflow outlet shall be sized in accordance with prevailing roof drainage sizing requirements.

(2) Water from the cistern overflow shall be discharged in a manner consistent with local stormwater runoff requirements and as approved by the local authority having jurisdiction.

(3) The overflow outlet shall include a line size, and readily accessible, backwater valve.

c. The vent shall be a minimum 38.1-mm (1.5-in.) diameter and be protected with 1.5-mm (0.06-in.) mesh to prevent the entry of vermin and particulates.

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4.5 Pump

4.5.1 Where a pump is provided in conjunction with the rainwater harvesting system, the pump shall meet the following provisions:

a. The pump and all other pump components shall be listed for the applicable use and approved for use with the appropriate potable or non-potable water systems.

b. The pump shall be capable of delivering the minimum required residual pressure at the highest and/or most remote outlet served. The minimum pump pressure shall allow for pipe friction loss, static lift, fixture requirements, and other pressure losses. The maximum pressure shall not exceed 653 kPa (80 psig), or as otherwise allowed by the local plumbing code. A pressure-reducing valve shall be provided at water branch distribution piping if the pump is capable of exceeding 618 kPa (75 psig).

4.6 Filtration

4.6.1 Filtration shall meet the following provisions:

a. Where rainwater is used for outdoor non-potable uses and for non-critical operations, such as drip irrigation, wash-down, etc., a final stage filtration system is not required.

b. Where rainwater is used for indoor non-potable use (e.g., for laundry, toilets, urinals, process, etc.), the water shall be filtered as a safeguard against sediment or discoloration and for proper operation of valves or other devices.

4.7 Piping

4.7.1 There shall be no direct connection of any rainwater harvesting pipe system and a public utility-provided domestic potable water pipe system without an approved backflow device.

4.7.2 Separation shall be maintained between potable and non-potable water systems at all times. Cross-connections, without proper protection in accordance with the local applicable plumbing code, shall not be permitted.

a. All material used as part of a rainwater harvesting system shall be listed for the applicable use for the purpose intended, as designated by the local applicable code.

b. On-site treated non-potable water pipes shall be permitted to be run or laid in the same trench as potable water pipes with a 305-mm (12-in.) minimum vertical and horizontal separation where both pipe materials are approved for use with a building and color-coded and labeled in accordance with Section 4.11. Where piping materials do not meet this requirement, the minimum separation shall be increased to 1,524 mm (60 in.). The potable water piping shall be installed at an elevation above the on-site treated non-potable water piping.

c. Underground pipes shall be installed below the local frost depth. Exception: where provisions to winterize the pipes are employed (e.g., irrigation system drainage).

d. Pipes exposed to the atmosphere, when the outdoor winter design temperature is 40°F or below, shall be provided with insulation and/or heat trace as required to prevent freezing.

4.7.3 Piping Materials

a. Rainwater distribution water piping, fittings, and other related system components shall be suitable for domestic water applications as indicated in the applicable local building and/or plumbing code, NSF Standard 61, or as otherwise described in Section 2.

b. Where plastic piping is exposed to UV radiation, it shall be protected by a factory-applied protective coating or painted with a compatible latex paint. Piping and solvent cements shall be approved for the intended use.

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4.8 System Inspection and Maintenance

4.8.1 Inspections and Cross-Connection Testing

4.8.1.1 Rainwater harvesting systems are considered a private water system under the responsibility of the building owner/operator and shall be minimally inspected according to the following schedule:

a. Inspection of all elements before they are covered (rough-in inspection).

b. Final inspection, including testing.

c. In addition to testing required by the code for plumbing systems, the following also apply:

(1) Testing and commissioning.

(2) Piping. A flow test shall be performed through the system to the point of water distribution and disposal. In addition, the water distribution system shall be tested and proved tight at the operating pressure. Where the manufacturer permits, a 446-kPa (50-psi) hydrostatic test may substitute for the test above. All lines and components shall be watertight.

d. Other inspections as needed to ensure proper system operation.

4.8.1.2 When a portion of the rainwater catchment system is installed in a building, an initial cross-connection inspection and test should be conducted in accordance with local codes, followed by annual testing.

4.8.2 System Maintenance

4.8.2.1 It is the property owner's responsibility to maintain the rainwater harvesting system components according to the manufacturers' written recommendations.

4.8.2.2 Rainwater harvesting systems shall be maintained in functioning order for the life of the system.

a. Filtration and disinfection systems shall be serviced in accordance with the manufacturers' recommendations.

b. System Abandonment: If the owner of a rainwater harvesting system elects to cease use of or fails to properly maintain such system, the owner shall abandon the system. To abandon the system, the system owner shall minimally:

(1) Remove or disable all system connecting piping to a utility-provided water system.

(2) Replace the rainwater harvesting piping system with piping compliant with NSF 150 and 61. Where a potable pipe system is already in place, fixtures may be reconnected to the existing system.

(3) Secure the cistern from accidental access by sealing or locking tank inlets and access points, and/or filling with sand or equivalent.

4.9 Potable Water Applications

4.9.1 Prior to implementing a design project intended to deliver potable water for either individual or public potable water systems, check with the authority having jurisdiction having responsibility over public water systems for additional requirements that may exist.

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4.9.2 Collection surfaces for potable water applications shall be made of nontoxic material and meet the requirements noted in 4.1.1 above.

a. Painted surfaces are only acceptable if the paint has been listed for the applicable use to NSF Protocol P151 or NSF 61 to ensure the toxicity level of the paint is acceptable for drinking water contact. Lead-, chromium-, or zinc-based paints are not permitted.

b. Enameled steel.

c. Flat Roofs: Roof products shall be listed for the applicable use to NSF Protocol P151.

4.9.3 The following materials shall not be used in potable water applications:[2]

a. Wood /cedar shake roofing.

b. Copper roofing materials.

c. Lead flashing.

d. Biocide treated shingles of any type.

4.9.4 Cisterns

a. Water entering the cistern shall be maintained at a quiescent flow in the cistern by minimizing splashing and the disturbance of sediment in the bottom of the cistern.

b. For potable water applications, and recommended for maintaining good water quality, the pipe entering the cistern shall terminate in a return bend elbow pointed upward at the bottom of the tank, or an equivalent calming device.

c. Cistern outlets shall be provided with a floating inlet to draw water from the cistern just below the water surface, or the outlet shall be located at least 10 cm (4 in.) above the bottom of the cistern.

d. Cisterns shall be listed for the applicable use to NSF 61. Plastic tanks shall adhere to the requirements of NSF 61 and be constructed of virgin plastic.

e. Cisterns shall not be connected directly to a public or community water supply without approved backflow protection. Makeup water to rainwater storage tanks, when provided, may be made through a reverse pressure principle backflow device or an air gap per local plumbing codes.

f. If installed below-grade, cisterns shall be separated from sanitary waste piping at a distance as recommended by the local authority having jurisdiction or local plumbing codes and up gradient from septic field piping where applicable.

4.9.5 Filtration

a. Carbon filtration may be provided for the reduction of odor and organic chemicals and the improvement of taste.

b. Filtration and disinfection systems shall be located after the water storage tank and as close to the final point of use as possible.

c. Particulate filtration shall be installed upstream of all UV disinfection systems.

d. Particulate filtration shall be installed downstream of all ozone and chemical disinfection systems. The cistern tank or a separate contact tank shall be sized and utilized to provide adequate contact time.

[2] The use of bitumen/composition roofing, galvanized, zinc-coated metal, or copper is not recommended and should be used with caution.

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e. Filters shall be adequately sized to extend service time and must be capable of meeting NSF 42 for the reduction of taste or odor or NSF 53 for organic chemical or cyst removal based on the end use of the collected rainwater.

4.9.6 Water Disinfection

4.9.6.1 To conform to the minimum water quality standards for potable water specified in Table 4.1, one of the following disinfection methods shall be used:

a. Chlorination may be used with an automated demand feed system and, if used, shall enable adequate contact time and residual according to local health authorities.

b. Ozone may be used with an approved ozone system ensuring adequate contact time with the ozone. Provision must be made to off-gas ozone to a safe environment.

c. Ultraviolet disinfection may be used and shall be provided between final filtration (5-micron maximum) and final point of use. UV systems shall be listed for the applicable use per the requirements of NSF 55 Class A devices.

d. Other technologies may be used for disinfection if the product is certified by an accredited certification body to the performance requirements in the U.S. EPA Guide Standard and Protocol for Testing Microbiological Water Purifiers or to NSF Protocol P231.

Table 4.1: Stored Rainwater Minimum Quality Standards

Parameter	Intended End-Use Quality Level	
	Non-potable	**Potable[a]**
Escherichia coli (E. coli)	< 100 CFU / 100 ml	None detected
Heterotrophic Plate Count (HPC)	—	Less than 500 CFU/ml[b]
Turbidity	< 10 NTU[c]	< 0.3 NTU

[a] Potable water standards meet the U.S. Environmental Protection Agency's drinking water standard for pathogens.
[b] U.S. EPA recommended limit
[c] NTU = nephelometric turbidity unit
Note: Monitoring requirements vary greatly from state to state. Consult state and local guidelines for monitoring requirements.

Note: The user of this standard is advised to check with the local authority having jurisdiction prior to implementing a design project intended to deliver potable water. Additional requirements may exist and the potable water system may fall under the responsibility of a state, federal, or tribal agency having responsibility over public water systems.

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4.10 Operation and Water Quality Maintenance

4.10.1 Prior to Use: Prior to system operation, all debris will be removed from the collection surface and piping system. The cistern and distribution piping shall be cleaned with a sanitizing solution.

a. After several cycles of rainwater harvesting, an initial sample of the resultant accumulated water shall be tested for compliance according to the procedures listed in the latest edition of Standard Methods for the Examination of Water and Wastewater. Systems that cannot meet the minimum quality standards as listed in Table 4.1 shall be re-cleaned and then tested again, after several additional rain events, for compliance with the applicable standards. Should the water quality still not be achievable, the system shall be provided with an appropriate filtration/disinfection device noted in Sections 4.9.4 and 4.9.5.

b. For private water systems, prior to placing the water system into service, water quality testing, at a minimum, shall be performed for E. coli, total coliform, and heterotrophic bacteria using the minimum quality standards provided in Table 4.1.

Note: The user of this standard is advised to check with the local authority having jurisdiction prior to implementing a design project intended to deliver potable water. Additional requirements may exist, and the potable water system may fall under the responsibility of a state, federal, or tribal agency having responsibility over public water systems.

c. Public System

(1) In addition 4.10.1a and b, water shall be tested for Cryptosporidium and Legionella bacterium.

(2) Subsequent annual tests shall be made for total coliform, E. coli, heterotrophic bacteria, and any chemicals of concern.

(3) Records of test results shall be maintained for at least two years.

4.10.2 Water Quality Maintenance

a. The quality of the water for the intended application shall be verified at the point of use in accordance with the minimum requirements of Table 4.1, complying with the testing procedures set forth in the Standard Methods for the Examination of Water and Wastewater.

b. Non-potable water shall be tested every 12 months. Potable water shall be tested every three months. If Legionella pneumophila is detectable in amounts greater than 10 CFU/ml at the point of use, appropriate disinfection will be required.

c. Maintenance: Non-Potable

(1) Non-potable water shall not be applied aboveground in a spray application (irrigation, powerwash, etc.) without appropriate disinfection for airborne bacteria.

d. Maintenance: Potable

(1) For a potable public water system, one sample shall be analyzed for applications serving up to 1,000 persons. When the treated water shall serve 1,001–2,500 persons, two samples shall be analyzed, and for 2,501 persons and up, three samples shall be analyzed. Samples must come from the following locations when additional taps for sampling are available:

(a) One sample from the same location as the positive sample;

(b) One sample within five service connections upstream;

(c) One sample within five service connections downstream; and

(d) For systems serving 25–1,000 persons, a fourth sample from any other sampling site.

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(2) If refill of the cistern is required, replacement water shall be provided in a conveyance, and with procedures, as approved by the local health authority.

e. If the quality of the tested water cannot consistently be maintained at the minimum levels specified in Table 4.1, the system shall be equipped with an appropriate treatment device meeting the applicable NSF standard referenced in Section 2.

Note: The user of this standard is advised to check with the local authority having jurisdiction prior to implementing a design project intended to deliver potable water. Additional requirements may exist, and the potable water system may fall under the responsibility of a state, federal, or tribal agency having responsibility over public water system.

4.11 Labeling

4.11.1 If a rainwater harvesting system is applied to any building, facility, or residence, it shall be so indicated as follows:

a. All rainwater-supplied fixtures, not specifically treated for potable water use, shall be prominently labeled “NON-POTABLE — DO NOT DRINK”.

b. Non-potable water piping shall be designated by colored bands and solid color piping as specified by the authority having jurisdiction or national code agencies and labeled “NON-POTABLE — RAINWATER”.

c. Outlets and fixtures served with untreated rainwater shall be easily recognizable by the color purple or a symbol for non-potable water.

End of Normative Standard

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APPENDIX A: ADDITIONAL RELEVANT STANDARDS/DOCUMENTS (INFORMATIVE)

1. ASTM International

ASTM D638-10: Standard Test Method for Tensile Properties of Plastics

ASTM D695-10: Standard Test Method for Compressive Properties of Rigid Plastics

ASTM D1599-11: Standard Test Method for Resistance to Short-Time Hydraulic Pressure of Plastic Pipe, Tubing, and Fittings

ASTM D1600-08: Standard Terminology for Abbreviated Terms Relating to Plastics

ASTM E84-12b: Standard Test Method for Surface Burning Characteristics of Building Materials

ASTM F412-12: Standard Terminology Relating to Plastic Piping Systems

2. International Association of Plumbing and Mechanical Officials (IAPMO)

Uniform Plumbing Code

Water Efficiency and Sanitation Standard for the Built Environment (We•Stand)

3. International Code Council (ICC)

International Plumbing Code

International Green Construction Code

4. International Organization for Standardization (ISO)

ISO 899-1 (2003): Plastics—Determination of Creep Behavior

5. National Weather Service (NWS)

NWS HYDRO-35: Five to 60-Minute Precipitation Frequency for the Eastern and Central United States

6. National Oceanic and Atmospheric Administration (NOAA)

National Climate Data Center (ncdc.noaa.gov)

NOAA's National Climatic Data Center Climate Normals 1981–2010

7. Plumbing-Heating-Cooling Contractors Association (PHCC)

National Standard Plumbing Code

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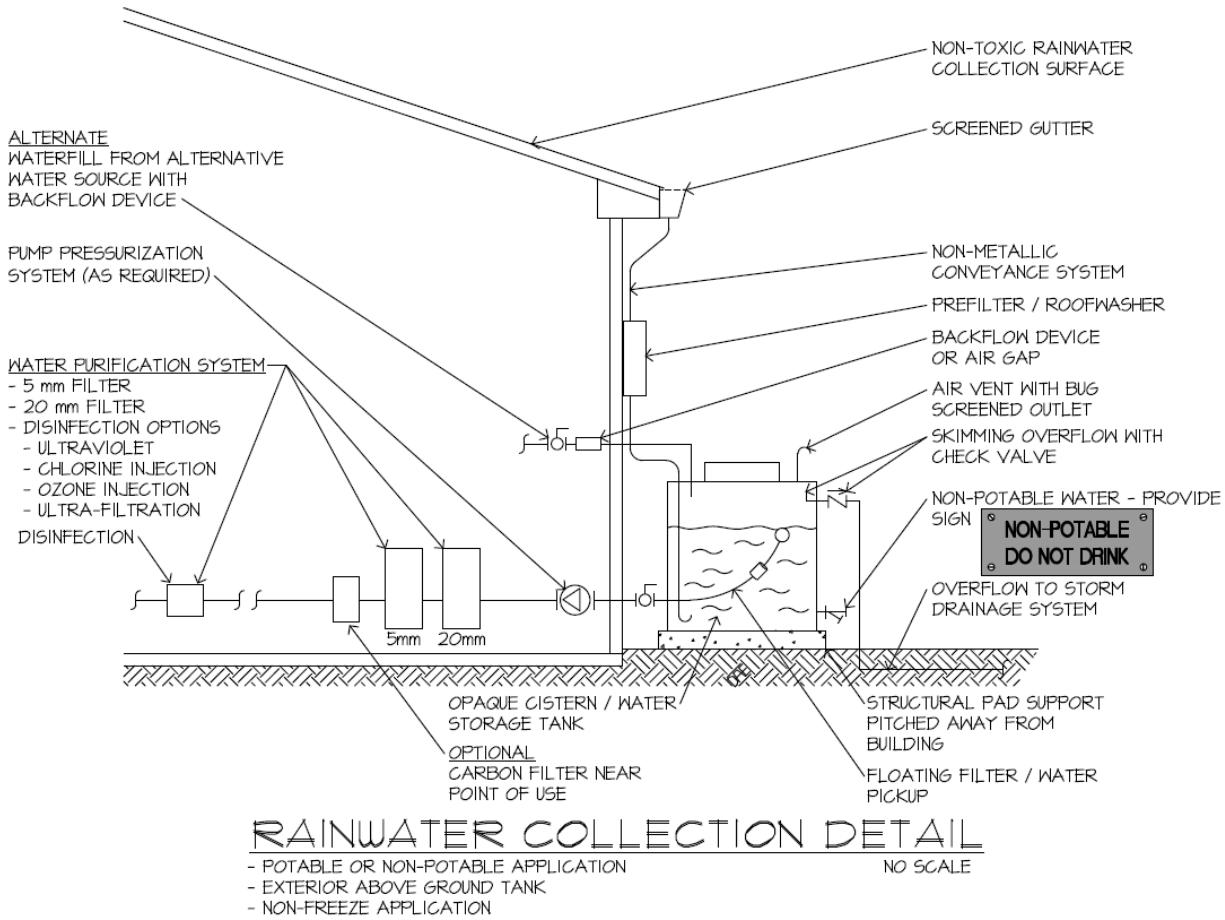
APPENDIX B: EXAMPLE PIPING SCHEMATICS (INFORMATIVE)

Aboveground Exterior Cistern for Potable and/or Non-potable Water

Figure B.1 shows an aboveground application in a non-freeze environment. In an environment where freezing is possible, the tank should be located in a heated environment, buried below the frost line, as shown in Figures B.2 and B.3, or otherwise heated or winterized to accommodate freezing conditions without system damage.

Figure B.1: Aboveground Exterior Cistern for Potable and/or Non-potable Water

Note: The user of this standard is advised to check with the local authority having jurisdiction prior to implementing a design project intended to deliver potable water. Additional requirements may exist, and the potable water system may fall under the responsibility of a state, federal, or tribal agency having responsibility over public water systems.



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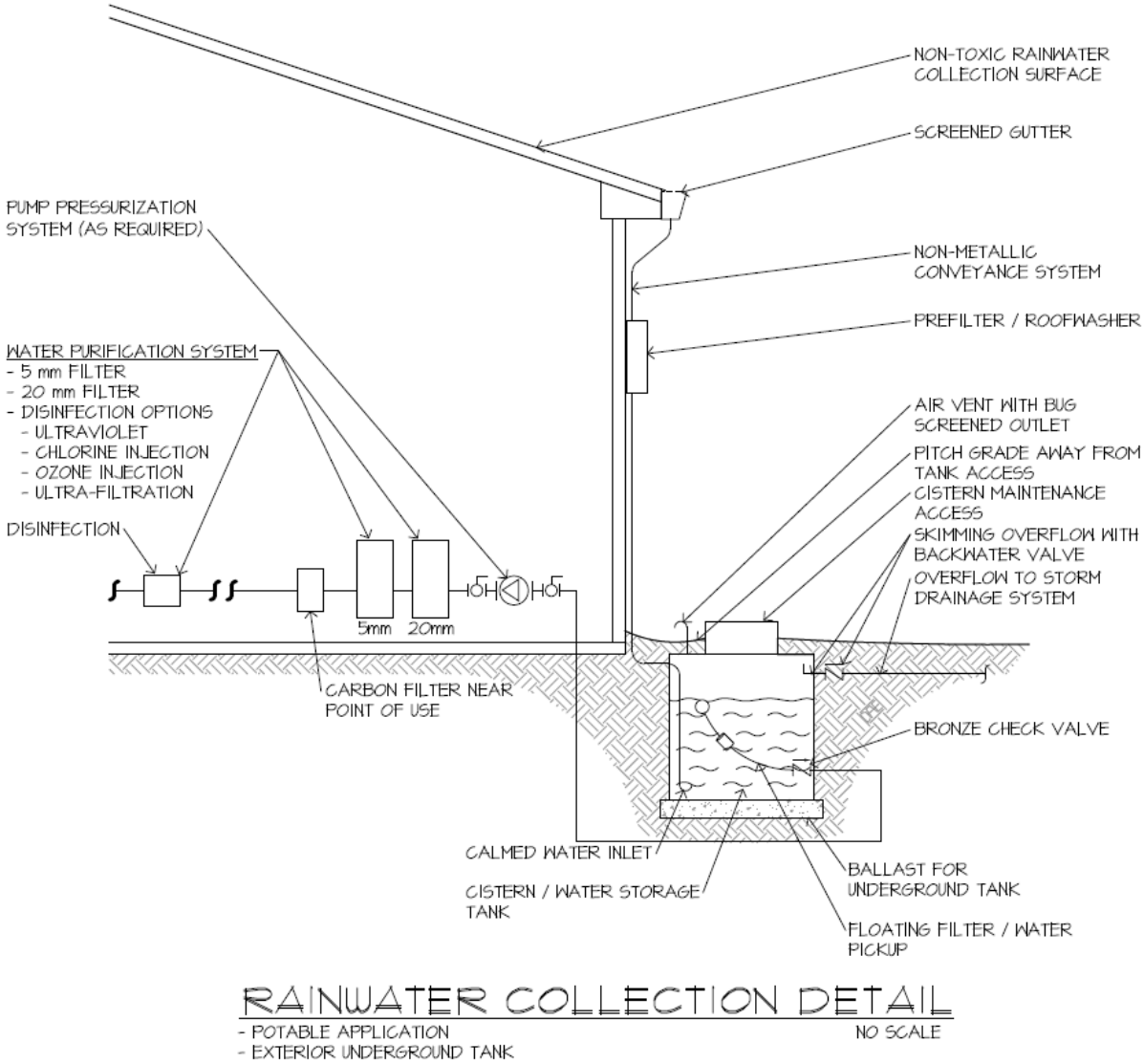
Underground Exterior Cistern for Potable Application

Where carbon filters are used, they may be put downstream of chlorine and ozone disinfection systems, but are recommended to be upstream of ultraviolet disinfection systems (see Figure B.2).

Figure B.2: Underground Exterior Cistern for Potable Application

Note: The user of this standard is advised to check with the local authority having jurisdiction prior to implementing a design project intended to deliver potable water. Additional requirements may exist, and the potable water system may fall under the responsibility of a state, federal, or tribal agency having responsibility over public water systems.



Where soil saturation is a possibility, it is recommended that the combined weight of the tank and ballast must meet or exceed the buoyancy upward force of an empty cistern. This buoyancy force is calculated as follows:

For 3,785-liter tank, buoyant force = 3,785 kg (1 liter = 1 kg)

[For 1,000-gallon tank, buoyant force = (1,000 gallons/7.48) x 62.4 lbs/cubic foot = 8,342 lbs]

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Buoyancy force of cistern (kg) = 1,000 liters x 1 kg/liter = 1,000 kg

[Buoyant force of cistern (lbs) = Volume (cubic feet) x 62.4 (lbs/cubic foot)]

If concrete is used for ballast, the volume needed will be:

Volume (cubic meters) = 1,000 kg x cubic meters/2,400 kg = 0.42 cubic meters

[Volume (cubic feet) = 8,342 lbs x cubic feet/150 lbs = 55.6 cubic feet (2.1 cubic yards)]

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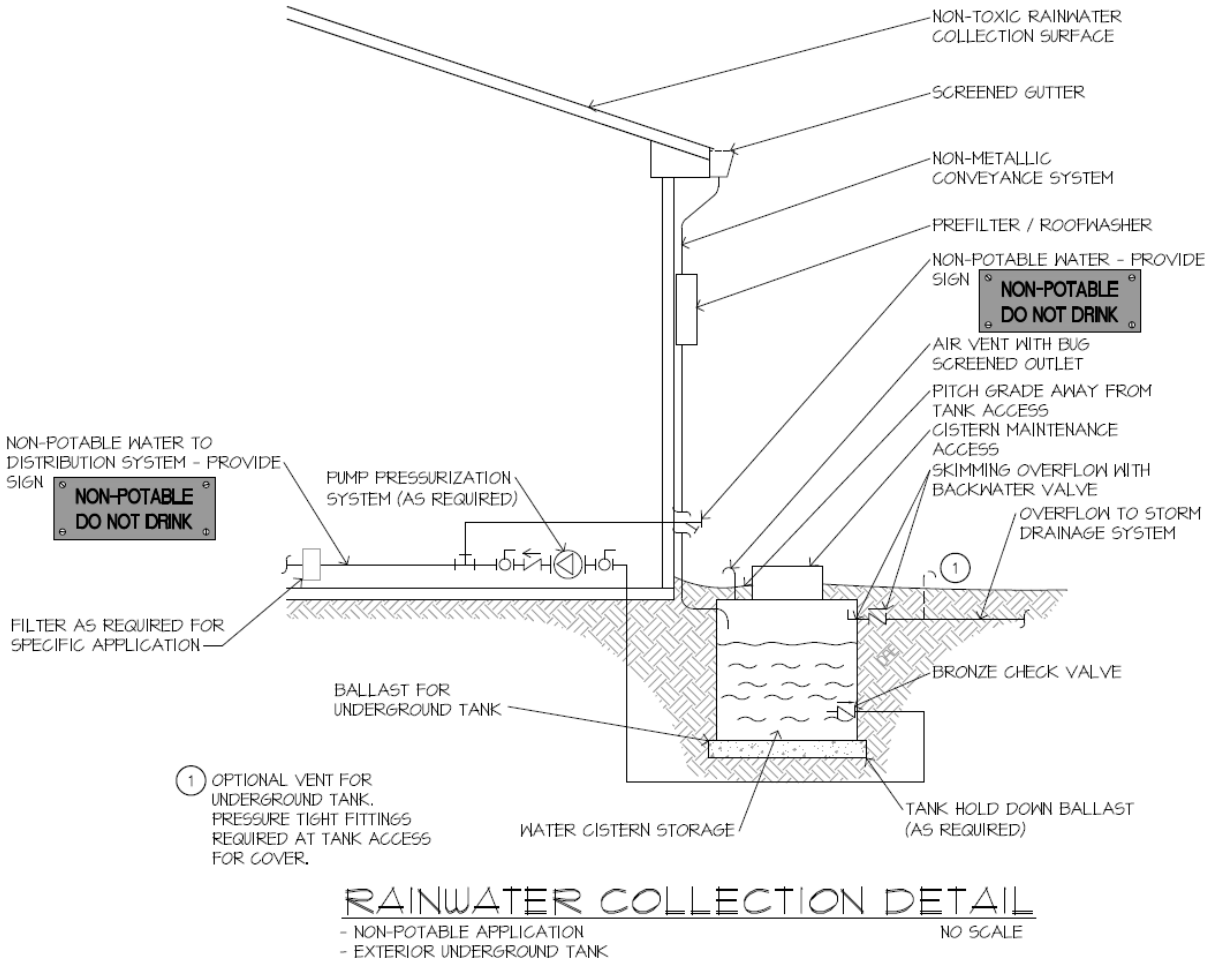
Underground Exterior Cistern for Non-potable Water

This application is suitable for indoor toilet and urinal flushing, lawn and plant irrigation, or process water makeup (see Figure B.3). Filters to remove particulates may be added to improve water quality or to avoid problems with sprinkler or process devices. Signage marking water outlets as “Non-potable — Do Not Drink” is required in a public environment and highly recommended elsewhere.

Figure B.3: Underground Exterior Cistern for Non-potable Water



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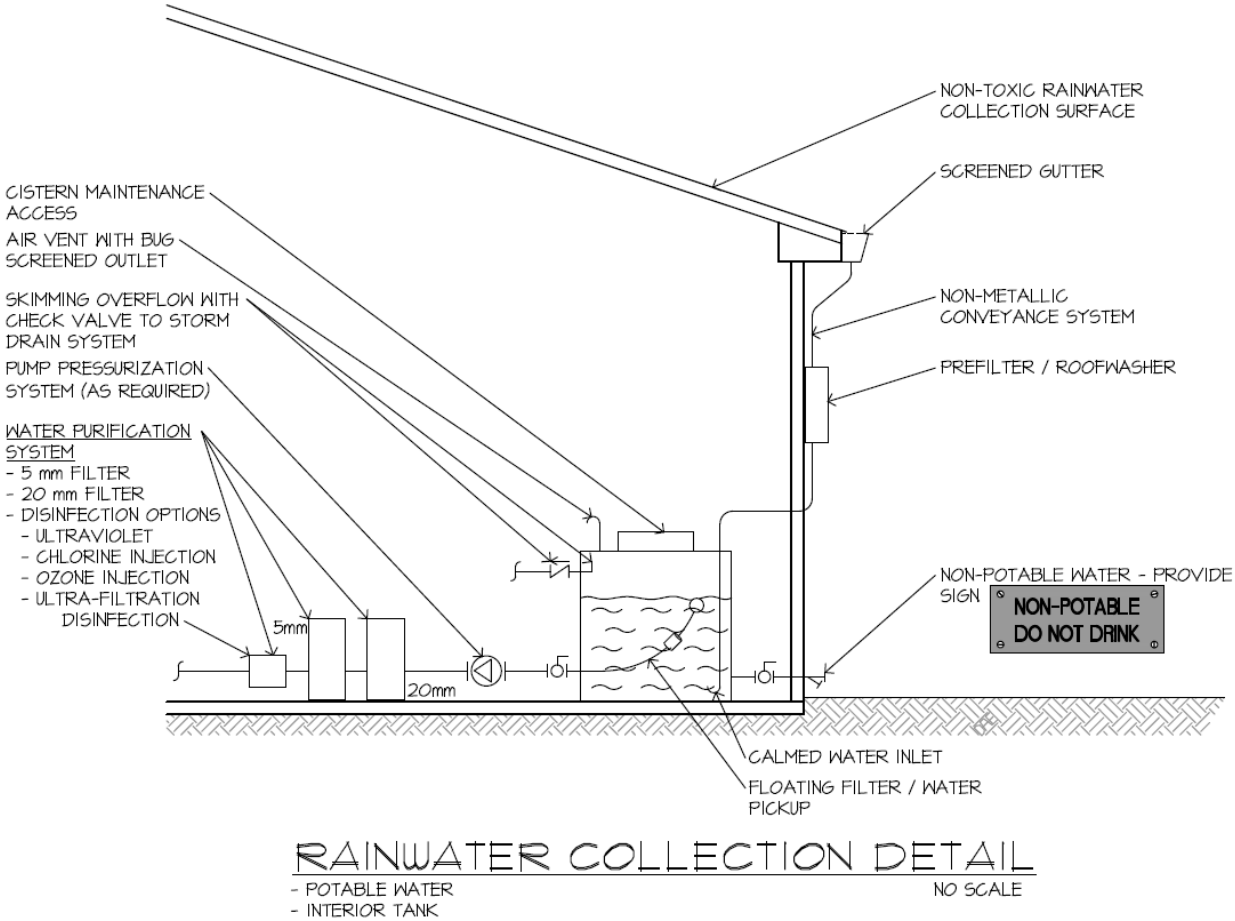
Aboveground Interior Cistern for Potable and Non-potable Water

Installing a water storage tank in a heated environment is preferred for an installation subject to freezing (see Figure B.4). Appropriate signage is necessary to label non-potable water outlets.

Figure B.4: Aboveground Interior Cistern for Potable and Non-potable Water

Note: The state drinking water primacy agency should be consulted for specific treatment, monitoring, reporting, and operator certification requirements. Treatment components are shown for illustration purposes only.



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First-Flush Devices

To supplement the pre-filtration of water entering the cistern, first-flush devices are commonly used to divert the initial water coming off the collection surface before being allowed to fill the cistern. Although first-flush devices are not required in many cases, they are recommended in the following cases:

1. Systems installed in areas that historically have long periods of time between rainstorms where fine debris and contaminants can accumulate over time.
2. Potable rainwater applications.

Commonly used roof wash amounts are indicated in Figure B.5, but may be varied to reflect actual site and seasonal conditions.

Figure B.5: Estimated Roof Contamination Potential

High Contamination[a]	Medium Contamination	Low Contamination[b]
5.0 mm (0.20 in.)	2.0 mm (0.08 in.)	0.5 mm (0.02 in.)

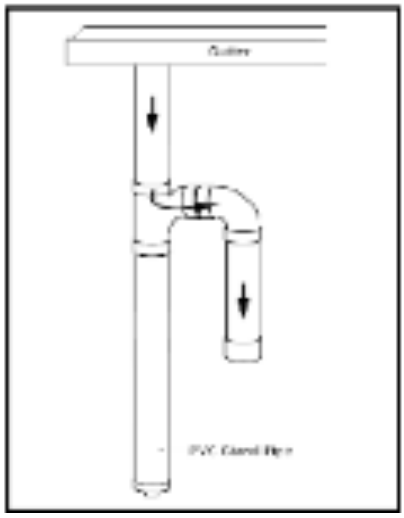
Sample calculation: 1,000-square-foot collection surface, medium contamination

Liters = 0.08 in. rain x 1,000 sf x 2.36 liters/sf-in. = 188.8 liters
[Gallons = 0.08 in. rain x 1,000 sf x 0.623 gallons/sf-in. = 49.8 gallons]

[a] High contamination is considered to have high content of organic debris from animal waste, adjacent trees, and/or airborne contamination.
[b] Low contamination is considered to either have frequent rainfall to keep the collection surface clean and/or minimal nontoxic contamination.

Many different styles of roof wash devices are available. The simplest versions involve filling a standpipe section of piping that contains adequate volume, that once full, then overflows into the cistern (see Figure B.6).

Figure B.6: Simple Roof Wash Device



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The volume of pre-wash for a nominal 101-mm (4-in.) diameter PVC pipe can be determined as follows in Figure B.7a.

Figure B.7a: 101-mm (4-in.) PVC Pipe Storage Volume	
Length, meters (feet)	**Volume, liters (gallons)**
0.3 (1.0)	2.6 (0.7)
0.9 (3.0)	7.6 (2.0)
1.6 (5.0)	12.5 (3.3)
3.0 (10.0)	25.4 (6.7)
4.6 (15.0)	38.1 (10.5)

The volume of pre-wash for a nominal 152-mm (6-in.) diameter PVC pipe can be seen in Figure B.7b.

Figure B.7b: 152-mm (6-in.) PVC Pipe Storage Volume	
Length, meters (feet)	**Volume, liters (gallons)**
0.3 (1.0)	5.7 (1.5)
0.9 (3.0)	17.0 (4.5)
1.6 (5.0)	28.4 (7.5)
3.0 (10.0)	56.8 (15.0)
4.6 (15.0)	85.2 (22.5)

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APPENDIX C: REFERENCE DEFINITIONS (INFORMATIVE)

The following terms are commonly used in the rainwater catchment system industry, and the definitions are provided for informational purposes.

AUXILIARY SUPPLY: A water supply arranged and protected from contamination that is available to provide an alternate means of filling a cistern.

CALMING INLET: A device that permits water to enter a storage tank with minimal disturbance to particles that may have settled to the bottom of the tank. See Quiescent Flow.

COLLECTION AREA: Area from which rainwater is collected for use in a rainwater harvesting system (e.g., roof area).

DRY RUN PROTECTION: System for protecting the water pump against running dry.

EVAPORATION FIELD: Element in the ground that is filled with gravel, ballast, or special non-permeable plastic elements and that stores rainwater that is fed into it on an intermediate basis before the water evaporates into the atmosphere or seeps into the surrounding soil.

FIRE SPRINKLER RESERVE: Volume of water needed for fire protection that is not available for any other use and accessible only by the fire pump.

HARVESTED WATER: Water gathered for the purpose of using for potable, non-potable, or industrial applications.

LEACH FIELD, EVAPORATION/TRANSPIRATION FIELD: Element in the ground that is filled with gravel, ballast, or special permeable plastic elements and that stores rainwater that is fed into it on an intermediate basis before the water seeps into the surrounding soil.

MINIMUM WATER VOLUME: Recoverable water volume that is constrained by the process such that neither sediment nor scum can be sucked into the deliverable water.

OVERFLOW DRAINAGE SYSTEM: Secondary roof drainage systems, set at a higher elevation than the primary roof drains, provided to convey rainwater from the roof surface.

OVERFLOW LEVEL: The highest level that water from a drainage system can rise.

OVERFLOW PIPE: Pipe for leading away rainwater when the rainwater reservoir is full (e.g., into the storm drain system or seepage system).

PRECIPITATION CHARACTERISTICS: Characteristics of a precipitation event (e.g., intensity, duration).

PROCESS WATER PIPING: System of pipes from the process water pump to the individual points at which water is drawn.

PROCESS WATER PUMP: Pump that processes water from the rainwater reservoir to the points at which it is drawn.

PROCESS WATER REQUIREMENTS: Planning value for the process water amount that is expected to be required in a specified period of time.

PURIFICATION: The process of removing microbial and other contaminates.

QUANTITY OF PRECIPITATION: Precipitation at a certain place, expressed as the water height over a horizontal area for a span of time under consideration.

RAINWATER PIPING: Supply, drainage, overflow, and emptying pipes of a rainwater harvesting system.

RAINWATER YIELD: Net water volume (water inflow), determined over a certain period of time, available for use as process water. Typically this is approximately 80 percent of theoretical collectable rainwater.

SUBSURFACE IRRIGATION: Water that is applied below ground level and is not directly exposed to the aboveground surface and/or surrounding air.

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SUPPLEMENTAL SUPPLY: Equipment for providing a supplemental supply of drinking water or non-drinking water into process water systems.

SYSTEM CONTROL UNIT: Control unit for the automatic operation of the rainwater harvesting system.

TRANSFER PUMP: A mechanical device to transfer collected water from downspouts to remote cisterns.

USEFUL VOLUME: Volume that can be completely used during operation (typically 80–90 percent of storage volume).

YIELD COEFFICIENT: Ratio of the rainwater annually flowing into the rainwater harvesting system to the total amount of rainwater in the accompanying precipitation area, allowing for leakage, splashing, evaporation, etc. (typically 0.75–0.90).

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APPENDIX D: EXAMPLE MAINTENANCE FORM (INFORMATIVE)

Note: The state drinking water primacy agency should be consulted for specific treatment, monitoring, reporting, and operator certification requirements. Treatment components are shown for illustration purposes only.

Maintenance Worksheet for

_____

	Change UV Light	**Change or Rinse Filters**	**Test for Bacteria**	**Clean First Flush**	**Check for Leaks**	**Test for Giardia/ Cryptosporidium**
Frequency	**Annually**	**Quarterly or as Needed**	**Quarterly**	**Quarterly or After Each Rain**	**After Each Rain or Quarterly**	**Initially and as Required**
Date Done						
Date Done						
Date Done						
Date Done						

Date	Meter Reading	Date	Meter Reading	Date	Meter Reading	Date	Meter Reading	Date	Meter Reading

Installer Name: _____ Phone: _____

Test Water: _____

Health Department Address: _____

Health Department Phone: _____ (retain all records)

Order UV Light from: _____Size: _____

Order Filters from: _____

Filter Size and Specs: _____

DRAFT

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APPENDIX E: CALCULATION PROCEDURE (INFORMATIVE)

Step 1: Estimate demand

Interior Water Requirement: On average, a conserving American household uses 171 liters (45.2 gallons) per person per day to operate toilets, showers, clothes washers, sinks, and other water-using fixtures and appliances. Water demand can be minimized by using water-efficient water fixtures. An example of how to estimate water demand is shown in Table E.1.

Table E.1: Water Demand Estimations

Residential Indoor Water Use

Fixture	Flow rate	Average # uses/day or min/day/ person	Daily demand/ person, L (gal)	Number of people in household	Total household daily demand, L (gal)	Total household monthly demand, L (gal)	Total household yearly demand, L (gal)
Toilet	6 Lpf (1.6 gpf)	5.1	30.89 (8.16)	3	92.67 (24.48)	2,809 (742)	33,823 (8,935)
Shower	6.3 Lpm (1.66 gpm, based on 2.5 gpm)	5.3	33.31 (8.8)	3	99.9 (26.39)	3,028 (800)	36,469 (9,634)
Faucet	6.3 Lpm (1.66 gpm, based on 2.5 gpm)	8.1	50.91 (13.45)	3	152.7 (40.34)	4,626 (1,222)	55,733 (14,723)
Dishwasher (1997–2001)	17 L/use (4.5 gal/use)	0.1	1.7 (0.45)	3	5.11 (1.35)	155 (41)	1,866 (493)
Clothes washer (1998–2001)	102.2 L/use (27 gal/use)	0.37	37.82 (9.99)	3	113.45 (29.97)	3,437 (908)	41,409 (10,939)
Total demand					463.83 (122.5)	14,055 (3,713)	169,300 (44,724)

Source: *Handbook of Water Use and Conservation*, Amy Vickers, Waterplow Press, Amherst, MA, 2001

Irrigation Water Requirement

Water used to irrigate landscaping often equals or exceeds interior water use. Supplemental irrigation water requirements can be greatly reduced by the use of 76 mm (3 in.) or more of top mulch, selecting native plants or plants that thrive in regions with a similar climate, and using passive rainwater techniques. Because plant water needs vary greatly depending on soils, climate, plant size, etc., it is recommended that a calculator for your region be referenced. For calculators, visit the ARCSA website at www.arcsa.org.

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Step 2: Sizing the Collection System

The collection surface is often dictated by architectural constraints, such as roof area, etc. The amount of surface area, based on the needed water volume, is described as follows:

Surface area (m^2) = Demand (liters) / [Precipitation density (mm) x system efficiency]

Surface area (ft^2) = Demand (gallons) / [0.623 x Precipitation density (in.) x system efficiency]

Note:

- 0.623 conversion factor = 7.48 (gallons/cubic foot) / 12 (inches/foot) = 0.623 gallons
- Surface area is horizontal projection of roof surface and not actual surface area (measure the area the roof covers, not the actual roof).
- Precipitation density period is consistent with time period being considered (monthly, yearly, etc.).
- This coefficient accounts for collection system loss from leakage, evaporation, roof composition, etc. Roof coefficients are approximately 0.80–0.85.

Step 3: Sizing the Storage

(Adapted from Martin, T.J., "Supply aspects of domestic rainwater tanks," South Australian Department of Environment, Adelaide, 1980.)

Once the area of roof catchment has been determined and the average rainfall has been established, the maximum amount of rain that can be collected can be calculated using the formula:

Runoff (gal) = A x (Rainfall – B) x Roof area

where:

A = efficiency of collection, and values of 0.80–0.85 (i.e., 80–85 percent efficiency) have been used

B = loss associated with adsorption and wetting of surfaces, and a value of 0.08 in. per month (2.0 in. per year) has been used

Rainfall should be expressed in inches and roof area in square feet.

The maximum volumes of rainwater that can be collected from various areas of roof and at a range of average annual rainfalls are shown in Appendix F. This information should only be used as an initial guide. If the maximum volumes are less than the annual water demand, then either the catchment area will need to be increased or the water demand will need to be reduced.

The next step is to calculate the size of the tank. The tank needs to be large enough to ensure that:

1. The required volume of water can be collected and stored in the tank.
2. The volume of water in the tank will be sufficient to meet demand during the drier months or through periods of low or no rainfall.

The simplest way of checking a tank size estimated to provide water throughout an average year is to use monthly rainfall data and to assume that at the start of the wetter months the tank is empty. The following formula should then be used for each month:

Vt = Vt – 1 + (Runoff – Demand)

where:

Vt = theoretical volume of water remaining in the tank at the end of the month

Vt – 1 = volume of water left in the tank from the previous month

Runoff should be calculated as discussed above (A = 0.80, B = 0.08 in.).

Starting with the tank empty, then Vt – 1 = 0. If after any month Vt exceeds the volume of the tank, then water will be lost to overflow. If Vt is ever a negative figure, then demand exceeds the available water. Providing the

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calculated annual runoff exceeds the annual water demand, Vt will only be negative if periodical overflows reduce the amount of water collected so that it is less than the demand.

Tank size is not necessarily based on collecting total roof runoff. For example, the maximum water that can be collected from a roof area of 20 square feet with a monthly rainfall of 4 in. will be about 49 gallons. If the water demand is less than this, some overflow may occur while demand is still met. If water demand is to be met throughout the month, the tank should be large enough so that Vt is never negative.

Calculations should be repeated using various tank sizes until Vt is 0 at the end of every month. The greater the values of Vt over the whole year, the greater the security of meeting water demand when rainfalls are below average or when dry periods are longer than normal.

The greater the security, the higher the cost of the tank.

Step 4: System Adjustment

To optimize performance and cost, going back through the calculation and modifying surface area and the cistern storage capacity is recommended.

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APPENDIX F: AVERAGE RAINFALL DATA (INFORMATIVE)

Average Rainfall Normals, 1981–2010 (centimeters)													
	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
BIRMINGHAM AP, AL	12.3	11.5	13.3	11.1	12.7	11.1	12.2	10.0	9.9	8.7	12.3	11.3	136.4
HUNTSVILLE, AL	12.4	12.3	13.2	11.0	13.0	10.9	10.3	9.2	9.4	9.1	12.5	14.7	138.0
MOBILE, AL	14.4	12.2	16.3	11.6	13.5	16.2	16.4	15.6	13.5	10.4	12.7	13.0	165.8
MONTGOMERY, AL	11.8	13.4	15.1	10.2	9.0	10.3	13.3	10.1	10.1	7.4	11.7	12.3	134.8
ANCHORAGE, AK	1.9	1.8	1.5	1.2	1.8	2.5	4.6	8.3	7.6	5.2	2.9	2.8	42.1
ANNETTE, AK	27.3	18.6	20.4	17.2	14.1	12.4	11.8	17.7	24.9	35.4	31.2	27.2	258.1
BARROW, AK	0.3	0.4	0.2	0.4	0.5	0.8	2.5	2.7	1.8	1.0	0.5	0.4	11.5
BETHEL, AK	2.0	1.8	1.8	1.9	2.9	4.4	6.0	8.3	7.0	4.2	4.1	2.8	47.1
BETTLES, AK	2.1	2.2	1.5	1.5	2.2	3.6	6.0	6.7	4.9	2.6	2.3	2.3	37.8
BIG DELTA, AK	0.8	0.7	0.5	0.6	2.3	5.9	6.8	4.8	2.6	2.0	1.6	1.0	29.5
COLD BAY, AK	8.0	7.6	6.9	6.1	6.6	6.9	6.3	9.3	12.0	12.1	12.6	11.3	105.8
FAIRBANKS, AK	1.5	1.1	0.6	0.8	1.5	3.5	5.5	4.8	2.8	2.1	1.7	1.6	27.5
GULKANA, AK	1.2	1.3	0.8	0.6	1.7	3.6	4.6	4.6	4.0	2.6	1.8	2.0	28.6
HOMER, AK	6.7	4.3	4.2	2.7	2.1	2.1	3.9	5.9	8.4	6.5	7.1	7.8	61.8
JUNEAU, AK	13.6	10.5	9.6	7.5	8.6	8.2	11.7	14.6	21.9	21.9	15.2	14.8	158.2

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Average Rainfall Normals, 1981–2010 (centimeters)													
	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
KING SALMON, AK	2.6	1.9	1.8	2.5	3.2	4.2	5.8	7.5	8.1	5.3	3.5	3.1	49.5
KODIAK, AK	21.1	15.6	14.0	14.8	14.3	15.0	12.5	11.6	18.7	21.0	17.4	22.2	198.1
KOTZEBUE, AK	1.6	1.7	1.1	1.4	1.0	1.5	3.7	5.5	4.0	2.6	2.0	1.9	27.9
MCGRATH, AK	2.8	2.4	2.1	1.9	2.8	3.9	6.0	7.1	6.3	3.7	3.6	3.3	45.7
NOME, AK	2.4	2.4	1.7	1.9	2.2	2.5	5.4	8.2	6.2	4.1	3.1	2.7	42.7
ST. PAUL ISLAND, AK	4.0	3.3	2.7	2.7	2.9	3.4	4.7	7.8	7.6	7.9	7.3	5.7	60.1
TALKEETNA, AK	3.5	3.7	2.7	3.3	4.1	4.9	8.6	13.0	11.0	7.4	4.1	4.9	71.0
VALDEZ, AK	16.9	12.2	11.2	10.2	7.9	7.4	8.2	15.4	24.3	21.3	19.2	26.4	180.5
YAKUTAT, AK	34.7	27.6	28.0	23.3	20.9	16.2	20.0	35.7	53.6	55.8	36.7	41.4	394.0
FLAGSTAFF, AZ	5.2	5.5	5.4	2.9	1.6	0.9	6.6	7.9	6.0	4.2	4.5	4.7	55.5
PHOENIX, AZ	2.3	2.3	2.5	0.7	0.3	0.1	2.7	2.5	1.6	1.5	1.7	2.2	20.4
TUCSON, AZ	3.3	2.9	2.1	1.1	1.1	1.4	5.4	7.7	4.2	2.8	2.5	3.4	37.8
WINSLOW, AZ	1.3	1.2	1.4	0.7	0.8	0.5	2.6	3.0	2.2	1.3	1.3	1.4	17.8
YUMA, AZ	1.0	0.7	0.7	0.2	0.1	0.1	0.6	1.5	0.7	0.7	0.4	1.1	M
FORT SMITH, AR	7.1	7.0	9.8	10.9	13.9	10.9	8.4	6.6	10.3	11.0	11.3	8.4	115.5
LITTLE ROCK, AR	9.0	9.3	11.9	13.1	12.4	9.3	8.3	6.6	8.1	12.5	13.4	12.6	126.4
NORTH LITTLE ROCK, AR	8.7	9.3	12.1	12.2	12.6	8.4	9.7	7.1	8.4	12.2	13.7	12.7	127.1
BAKERSFIELD, CA	2.9	3.1	3.1	1.3	0.5	0.2	0.0	0.1	0.2	0.8	1.6	2.6	16.4
BISHOP, CA	2.7	2.2	1.3	0.7	0.5	0.5	0.4	0.3	0.5	0.8	1.3	2.0	13.2
EUREKA, CA	16.5	14.3	13.5	8.4	4.5	1.9	0.5	0.8	1.5	5.7	14.2	20.6	102.4
FRESNO, CA	5.6	5.2	5.2	2.4	1.1	0.5	0.0	0.0	0.4	1.6	2.7	4.5	29.2
LONG BEACH, CA	6.6	7.8	4.7	1.5	0.5	0.2	0.1	0.1	0.5	1.6	2.5	5.0	31.1
LOS ANGELES AP, CA	6.9	8.3	4.7	1.8	0.6	0.2	0.1	0.1	0.5	1.4	2.8	5.2	32.6

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Average Rainfall Normals, 1981–2010 (centimeters)													
	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
LOS ANGELES CO., CA	7.9	9.7	6.2	2.3	0.7	0.2	0.0	0.1	0.6	1.7	2.6	5.9	37.9
REDDING, CA	15.6	23.9	19.7	9.6	5.9	3.2	1.1	1.2	2.2	7.4	13.1	18.4	121.3
SACRAMENTO, CA	9.2	8.8	7.0	2.9	1.7	0.5	0.0	0.1	0.7	2.4	5.3	8.3	47.0
SAN DIEGO, CA	5.0	5.8	4.6	2.0	0.3	0.2	0.1	0.1	0.4	1.4	2.6	3.9	26.3
SAN FRANCISCO AP, CA	10.6	10.3	7.5	3.3	1.2	0.3	0.0	0.1	0.4	2.4	6.0	10.2	52.5
SAN FRANCISCO C.O., CA	11.4	11.3	8.3	3.7	1.8	0.4	0.0	0.2	0.5	2.8	8.0	11.6	60.1
SANTA BARBARA, CA	8.9	10.1	8.1	2.5	0.9	0.2	0.1	0.3	0.7	2.1	3.9	7.5	45.1
SANTA MARIA, CA	7.0	7.6	6.7	2.5	0.8	0.1	0.1	0.1	0.4	1.5	3.4	5.4	35.4
STOCKTON, CA	7.0	6.5	5.5	2.5	1.3	0.2	0.0	0.0	0.7	2.1	4.3	5.6	35.7
ALAMOSA, CO	0.7	0.7	1.3	1.5	1.5	1.2	2.5	3.2	2.3	1.7	1.1	0.9	18.6
COLORADO SPRINGS, CO	0.8	0.9	2.5	3.6	5.2	6.4	7.2	8.5	3.0	2.1	1.0	0.9	42.0
DENVER, CO	1.0	0.9	2.3	4.3	5.4	5.0	5.5	4.3	2.4	2.6	1.5	0.9	36.3
GRAND JUNCTION, CO	1.5	1.4	2.3	2.3	2.2	1.2	1.5	2.4	3.0	2.7	1.9	1.5	23.9
PUEBLO, CO	0.9	0.8	2.4	3.6	3.8	3.5	5.2	5.9	2.0	1.8	1.2	1.0	31.9
BRIDGEPORT, CT	7.9	7.1	10.3	10.5	9.7	9.2	8.8	10.1	8.8	9.2	8.6	8.5	108.6
HARTFORD, CT	8.0	6.7	9.1	9.9	9.9	10.1	10.2	9.3	8.8	10.5	9.8	8.5	110.7
WILMINGTON, DE	7.6	6.8	10.0	8.9	10.0	9.9	11.6	8.3	11.0	8.7	7.9	8.8	109.4
WASHINGTON DULLES AP, DC	6.8	7.0	8.6	8.8	11.6	10.1	9.3	9.0	10.0	8.3	8.7	7.5	105.5
WASHINGTON NAT'L AP, DC	7.1	6.7	8.8	7.8	10.1	9.6	9.5	7.4	9.4	8.6	8.1	7.7	100.9
APALACHICOLA, FL	11.2	10.5	13.4	7.8	6.4	13.4	18.0	20.9	17.1	10.7	8.9	8.4	146.6
DAYTONA BEACH, FL	7.0	7.1	10.8	5.5	8.0	14.8	14.8	16.3	17.7	10.7	6.8	6.7	126.0
FORT MYERS, FL	4.9	5.5	7.3	5.5	6.7	25.6	23.0	25.8	21.1	7.3	5.0	4.3	142.1
GAINESVILLE, FL	8.5	8.1	11.0	6.8	6.3	18.1	15.4	16.2	11.2	7.3	5.2	6.0	120.2
JACKSONVILLE, FL	8.4	8.1	10.0	6.7	6.3	16.4	16.6	17.3	20.8	10.0	5.4	7.1	133.1
KEY WEST, FL	6.0	4.4	5.1	5.8	8.9	13.1	10.5	18.6	22.8	12.8	5.4	5.6	119.0

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MIAMI, FL	4.1	5.7	7.6	8.0	13.6	24.6	16.5	22.6	25.0	16.1	8.3	5.2	157.2
ORLANDO, FL	7.0	7.2	9.6	6.3	8.4	22.2	18.0	19.9	15.3	8.4	6.1	6.7	135.1
PENSACOLA, FL	11.5	13.0	13.9	10.3	10.4	14.5	18.8	14.7	15.6	12.5	9.8	10.5	155.4
TALLAHASSEE, FL	11.0	12.3	15.1	7.8	8.8	19.6	18.2	18.7	11.9	8.2	8.9	9.9	150.4
TAMPA, FL	5.7	7.1	7.7	5.2	5.3	17.0	18.0	19.7	16.0	5.7	3.9	6.3	117.6
VERO BEACH, FL	6.4	6.8	10.5	6.9	8.5	16.9	14.3	17.9	17.2	12.5	8.3	5.6	131.7
WEST PALM BEACH, FL	8.0	7.2	11.7	9.3	11.5	21.1	14.6	20.2	21.2	13.0	12.1	8.6	158.3
ATHENS, GA	10.3	11.4	11.3	8.0	7.6	10.6	11.4	9.0	10.0	9.0	9.7	9.5	117.7
ATLANTA, GA	10.7	11.9	12.2	8.5	9.3	10.0	13.4	9.9	11.4	8.7	10.4	9.9	126.3
AUGUSTA, GA	10.7	10.2	10.9	7.5	8.1	10.9	13.4	12.5	8.6	8.2	8.1	9.2	118.2
COLUMBUS, GA	9.8	11.3	13.9	9.0	8.1	9.4	12.1	9.6	7.8	6.6	10.4	10.8	118.7
MACON, GA	10.8	11.1	11.6	7.5	6.9	10.3	12.6	10.4	9.1	7.1	8.4	10.3	116.0
SAVANNAH, GA	9.4	7.1	9.5	7.8	7.6	15.1	14.2	16.7	11.6	9.4	6.0	7.5	121.8
HILO, HI	32.1	31.6	38.8	39.5	22.5	22.5	34.7	23.8	31.8	31.6	41.4	48.0	398.2
HONOLULU, HI	5.9	5.1	5.1	1.6	1.6	0.7	1.3	1.4	1.8	4.7	6.1	8.2	43.4
KAHULUI, HI	7.3	4.8	6.2	3.9	1.9	0.5	1.3	1.3	1.0	3.0	5.6	8.5	45.3
LIHUE, HI	9.5	8.0	11.7	5.7	5.3	4.1	4.7	5.4	5.4	9.7	11.3	13.2	94.1
BOISE, ID	3.1	2.5	3.5	3.1	3.5	1.8	0.8	0.6	1.5	1.9	3.4	3.9	29.8
LEWISTON, ID	2.7	2.0	2.9	3.4	4.1	3.1	1.7	1.8	1.7	2.4	3.0	2.5	31.3
POCATELLO, ID	2.5	2.5	3.2	2.9	3.7	2.5	1.6	1.5	2.1	2.2	2.8	3.1	30.8
CHICAGO, IL	4.4	4.5	6.4	8.6	9.3	8.8	9.4	12.4	8.2	8.0	8.0	5.7	93.7
MOLINE, IL	3.8	4.1	7.3	9.1	11.0	11.4	10.9	11.5	7.8	7.5	6.5	5.5	96.4
PEORIA, IL	4.5	4.5	7.1	9.2	11.0	9.0	9.8	8.2	8.0	7.2	8.0	6.1	92.7
ROCKFORD, IL	3.5	3.6	5.9	8.5	10.2	11.8	10.0	11.7	8.5	6.8	6.6	5.0	92.0
SPRINGFIELD, IL	4.6	4.6	6.7	8.9	10.8	11.3	10.0	8.2	7.4	8.0	8.2	6.4	95.1
EVANSVILLE, IN	7.9	8.1	10.8	11.1	13.6	9.6	10.0	7.6	7.7	8.3	11.0	9.6	115.1
FORT WAYNE, IN	5.7	5.2	6.9	8.9	10.8	10.6	10.8	9.2	7.1	7.2	7.8	7.0	97.4
INDIANAPOLIS, IN	5.6	5.4	8.4	9.9	13.4	11.2	10.8	8.1	5.7	7.9	9.4	7.8	103.6
SOUTH BEND, IN	5.8	5.0	6.1	8.2	9.7	9.6	10.2	9.6	9.0	8.4	8.3	6.6	96.5
DES MOINES, IA	2.3	3.1	5.7	9.4	11.8	11.9	11.4	12.0	7.9	6.4	5.5	3.4	91.0

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Average Rainfall Normals, 1981–2010 (centimeters)													
	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
DUBUQUE, IA	3.0	3.7	6.1	9.3	10.6	11.2	10.9	11.2	8.8	6.8	6.0	4.7	92.2
SIOUX CITY, IA	1.6	1.7	5.1	7.5	9.5	9.9	8.7	8.2	7.5	5.4	3.3	2.0	70.5
WATERLOO, IA	2.1	2.5	5.2	9.4	11.5	12.6	12.5	10.8	6.7	6.3	5.1	3.0	87.9
CONCORDIA, KS	1.5	2.0	5.1	6.2	10.6	10.3	10.0	8.0	7.4	4.9	2.8	2.2	70.8
DODGE CITY, KS	1.5	1.7	4.0	4.6	7.2	8.2	7.8	7.0	4.2	4.4	1.9	2.1	54.9
GOODLAND, KS	1.0	1.2	2.7	4.0	7.5	8.3	8.8	6.9	3.1	3.5	1.8	1.2	49.9
TOPEKA, KS	2.2	3.4	6.3	9.0	12.5	13.7	9.7	10.8	9.3	7.7	4.7	3.4	92.6
WICHITA, KS	2.1	3.0	6.8	6.6	11.6	13.2	8.4	9.4	8.0	7.1	3.6	3.0	82.9
GREATER CINCINNATI AP, OH	7.2	6.5	9.9	9.8	12.8	10.3	9.8	9.2	7.2	7.9	8.1	8.0	106.5
JACKSON, KY	9.2	9.5	10.5	9.7	13.2	11.9	11.8	9.4	8.8	8.1	10.1	10.6	122.8
LEXINGTON, KY	8.1	8.1	10.3	9.1	13.4	11.3	11.8	8.3	7.4	8.0	9.0	10.0	114.7
LOUISVILLE, KY	8.6	8.1	10.6	10.4	13.0	10.5	10.6	8.4	8.0	8.2	9.2	10.2	115.7
PADUCAH, KY	9.3	9.9	10.0	12.1	12.5	10.3	11.3	7.0	9.5	10.1	10.9	11.7	124.7
BATON ROUGE, LA	14.5	12.8	11.2	11.3	12.4	16.3	12.6	14.8	11.5	11.9	10.4	14.2	154.1
LAKE CHARLES, LA	13.3	8.8	9.3	8.5	13.2	17.4	14.3	12.3	13.4	12.4	11.3	11.9	146.0
NEW ORLEANS, LA	13.1	13.5	11.6	11.7	11.8	20.5	15.1	15.2	12.6	9.0	11.4	13.3	158.6
SHREVEPORT, LA	10.6	12.1	11.0	10.3	11.3	12.6	8.9	6.6	8.5	12.8	12.0	12.5	129.4
CARIBOU, ME	6.9	5.6	6.4	6.8	8.5	8.8	10.4	9.6	8.4	9.0	9.2	8.3	97.8
PORTLAND, ME	8.6	8.3	10.8	11.0	10.2	9.6	9.2	8.0	9.4	12.4	12.5	10.2	120.0
BALTIMORE, MD	7.7	7.4	9.9	8.1	10.1	8.8	10.3	8.4	10.2	8.5	8.4	8.6	106.4
BOSTON, MA	8.5	8.3	11.0	9.5	8.9	9.3	8.7	8.5	8.7	10.0	10.1	9.6	111.2
WORCESTER, MA	8.9	8.2	10.7	10.4	10.6	10.6	10.7	9.4	10.0	11.9	10.9	9.7	122.1
ALPENA, MI	4.2	3.4	4.7	6.1	6.8	6.7	7.7	8.2	7.4	6.6	5.3	4.4	71.5
DETROIT, MI	3.6	4.3	5.1	7.1	7.8	8.3	7.7	8.0	8.6	6.9	7.2	5.0	79.6
FLINT, MI	4.1	3.8	4.9	7.3	7.8	7.8	8.4	8.1	9.5	6.3	6.8	4.9	79.7
GRAND RAPIDS, MI	5.3	4.5	6.0	8.5	10.1	9.6	9.6	9.1	10.9	8.3	8.9	6.4	97.2
HOUGHTON LAKE, MI	3.8	3.1	4.7	6.3	7.2	7.9	7.0	8.6	7.9	6.5	5.9	4.2	73.0
LANSING, MI	4.2	3.7	5.2	7.7	8.5	8.8	7.2	8.2	8.9	6.4	7.1	4.7	80.7
MARQUETTE, MI	6.1	5.4	7.7	7.6	7.7	7.2	7.2	7.7	9.4	9.8	8.1	6.5	90.6
MUSKEGON, MI	5.2	4.6	5.7	7.4	8.3	6.5	6.0	8.6	9.9	7.9	8.5	6.5	85.1

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Average Rainfall Normals, 1981–2010 (centimeters)													
	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
SAULT STE. MARIE, MI	5.6	3.4	5.0	6.1	6.5	6.9	7.3	8.1	9.7	9.7	8.6	7.1	83.7
DULUTH, MN	2.4	2.1	3.8	6.2	8.2	10.7	9.8	9.4	10.4	7.2	5.3	3.1	78.6
INTERNATIONAL FALLS, MN	1.6	1.4	2.4	3.9	7.3	10.0	9.4	7.1	7.6	5.3	3.5	2.1	61.5
MINNEAPOLIS-ST. PAUL, MN	2.3	2.0	4.8	6.8	8.5	10.8	10.3	10.9	7.8	6.2	4.5	2.9	77.7
ROCHESTER, MN	2.2	2.1	4.8	8.2	9.2	11.9	11.6	11.5	8.8	5.7	4.9	3.1	83.9
SAINT CLOUD, MN	1.7	1.5	3.9	6.5	7.5	10.6	8.4	9.6	8.8	6.3	3.5	2.1	70.4
JACKSON, MS	12.7	11.2	13.0	13.0	12.3	10.5	11.6	10.2	8.2	10.1	12.1	13.2	138.0
MERIDIAN, MS	13.0	14.2	13.8	12.1	11.4	11.2	13.1	10.1	8.7	9.6	12.6	12.9	142.6
TUPELO, MS	11.4	12.6	12.2	12.1	14.1	11.5	9.9	8.8	8.7	10.5	11.9	16.0	139.7
COLUMBIA, MO	4.9	5.7	7.4	11.4	12.6	11.4	11.1	11.1	9.8	8.4	8.3	6.2	108.3
KANSAS CITY, MO	2.9	3.8	5.5	9.4	13.0	14.0	10.1	11.2	10.6	8.9	5.4	4.4	99.2
ST. LOUIS, MO	6.1	5.7	8.4	9.4	12.0	10.9	10.4	7.6	8.0	8.5	9.9	7.2	104.0
SPRINGFIELD, MO	6.3	6.4	9.2	11.0	13.0	12.3	9.3	9.0	11.7	9.1	10.7	7.7	115.7
BILLINGS, MT	1.2	1.2	2.7	4.2	5.5	5.4	3.4	1.9	3.3	3.0	1.6	1.3	34.7
GLASGOW, MT	0.9	0.7	1.1	2.2	4.9	5.9	4.5	3.1	2.4	1.9	1.0	1.0	29.6
GREAT FALLS, MT	1.3	1.2	2.3	3.6	6.1	6.4	3.8	4.0	3.6	2.2	1.5	1.4	37.5
HAVRE, TX	0.8	0.7	1.4	2.1	4.4	5.6	4.2	2.8	2.8	1.5	1.1	1.0	28.4
HELENA, MT	0.9	0.8	1.5	2.5	4.7	5.2	3.0	3.0	2.8	1.7	1.2	1.0	28.5
KALISPELL, MT	3.4	2.5	2.8	3.1	5.0	6.5	3.7	2.5	3.5	2.6	3.6	4.0	43.2
MISSOULA, MT	2.2	1.8	2.5	3.1	5.1	5.3	2.5	3.0	3.0	2.2	2.6	2.6	35.9
GRAND ISLAND, NE	1.3	1.7	4.6	6.4	11.2	10.9	8.6	7.9	5.7	4.7	3.0	1.6	67.7
LINCOLN, NE	1.6	1.9	5.3	6.5	11.5	11.4	9.1	8.2	7.7	5.2	3.6	2.4	74.3
NORFOLK, NE	1.5	1.9	4.5	6.7	10.0	10.8	8.4	8.3	6.8	5.3	3.5	1.9	69.6
NORTH PLATTE, NE	0.9	1.3	2.7	5.8	8.3	8.7	7.8	5.8	3.6	3.9	1.6	1.0	51.4
OMAHA EPPLEY AP, NE	1.8	2.2	5.1	7.5	12.1	10.6	9.7	9.7	6.8	5.5	4.2	2.6	77.8
OMAHA (NORTH), NE	1.8	2.2	5.4	8.7	11.9	10.5	10.0	9.0	7.3	6.1	3.8	2.6	79.3
SCOTTSBLUFF, NE	1.0	1.5	2.5	4.6	6.3	7.2	4.6	3.3	3.0	2.9	1.7	1.3	40.1
VALENTINE, NE	0.7	1.2	2.7	5.6	8.0	9.0	8.2	5.5	4.2	3.2	1.7	0.9	50.9

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Average Rainfall Normals, 1981–2010 (centimeters)													
	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
ELKO, NV	2.8	2.1	2.5	2.5	2.4	1.7	0.9	0.9	1.4	1.9	2.8	3.0	25.2
ELY, NV	1.8	1.9	2.4	2.4	2.8	1.7	1.6	2.3	2.1	2.5	1.8	1.5	24.8
LAS VEGAS, NV	1.4	1.9	1.1	0.4	0.3	0.2	1.0	0.8	0.6	0.7	0.9	1.3	10.6
RENO, NV	2.6	2.6	1.9	1.2	1.2	1.3	0.5	0.6	0.9	1.3	2.1	2.6	18.8
WINNEMUCCA, NV	2.2	1.7	2.1	2.3	2.8	1.4	0.6	0.5	1.1	1.7	2.2	2.4	21.0
CONCORD, NH	6.9	6.7	8.3	8.7	9.3	9.4	9.5	8.1	8.6	10.3	9.4	8.1	103.1
MT. WASHINGTON, NH	16.4	17.2	19.5	18.9	20.8	21.3	22.3	21.1	20.4	23.5	25.0	19.6	246.0
ATLANTIC CITY AP, NJ	8.2	7.3	10.7	9.2	8.5	7.9	9.4	10.4	8.0	8.7	8.3	9.4	106.0
ATLANTIC CITY C.O., NJ	7.8	7.3	10.2	8.6	8.2	6.8	8.4	10.0	7.8	8.8	8.5	9.2	101.6
NEWARK, NJ	9.0	7.3	10.6	10.7	10.4	10.2	12.1	9.4	9.7	9.1	9.3	9.7	117.5
ALBUQUERQUE, NM	1.0	1.2	1.4	1.5	1.3	1.7	3.8	4.0	2.7	2.6	1.4	1.3	24.0
CLAYTON, NM	0.7	0.9	2.4	2.4	5.0	5.4	6.8	7.5	4.2	2.8	1.1	0.9	40.1
ROSWELL, NM	1.0	1.1	1.3	1.5	3.2	4.4	5.2	5.0	3.9	3.1	1.5	1.6	32.8
ALBANY, NY	6.6	5.6	8.2	8.1	9.2	9.6	10.5	8.8	8.4	9.3	8.4	7.4	99.9
BINGHAMTON, NY	6.2	5.9	7.6	8.7	9.1	10.9	9.4	8.8	9.2	8.5	8.4	7.2	99.8
BUFFALO, NY	8.1	6.3	7.3	7.6	8.8	9.3	8.2	8.3	9.9	8.9	10.2	9.9	102.8
ISLIP, NY	9.2	8.3	11.3	11.0	9.6	10.8	8.7	10.1	9.1	9.6	9.3	10.3	117.4
NEW YORK C. PARK, NY	9.3	7.8	11.1	11.4	10.6	11.2	11.7	11.3	10.9	11.2	10.2	10.2	126.8
NEW YORK (JFK AP), NY	8.0	6.6	9.6	9.8	10.0	9.8	10.4	9.3	8.9	9.2	8.4	8.6	108.6
NEW YORK (LAGUARDIA AP),	8.1	7.0	10.1	10.2	9.6	10.0	11.4	10.5	9.5	9.6	8.7	9.0	113.6
ROCHESTER, NY	6.1	5.0	6.4	6.9	7.3	8.5	8.5	8.8	8.6	6.9	7.5	6.7	87.0
SYRACUSE, NY	6.4	5.3	7.5	8.1	8.2	8.4	9.6	9.1	9.4	8.7	9.0	8.2	97.7
ASHEVILLE, NC	8.9	8.8	10.4	9.2	9.8	12.8	13.7	11.2	10.1	7.2	11.0	9.3	122.3
CAPE HATTERAS, NC	13.3	10.2	12.1	9.2	9.1	10.2	12.7	17.6	15.9	13.7	12.6	10.8	147.4
CHARLOTTE, NC	8.7	8.4	10.2	7.7	8.1	9.5	9.3	10.7	8.2	8.6	8.0	8.3	105.7

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Average Rainfall Normals, 1981–2010 (centimeters)													
	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
GREENSBORO-WNSTN-SALM-HGH	7.8	7.5	9.5	9.1	8.6	9.5	11.4	9.9	10.6	8.0	7.9	7.6	107.2
RALEIGH, NC	8.9	8.2	10.4	7.4	8.3	8.9	12.0	10.8	11.1	8.3	7.9	7.8	110.1
WILMINGTON, NC	9.6	9.2	10.7	7.2	11.4	13.2	19.0	18.8	19.9	9.9	8.4	9.2	146.3
BISMARCK, ND	1.1	1.3	2.2	3.2	6.1	8.1	7.3	5.8	4.0	3.2	1.8	1.2	45.3
FARGO, ND	1.8	1.5	3.3	3.5	7.1	9.9	7.1	6.5	6.5	5.5	2.5	2.1	57.4
GRAND FORKS, ND	1.4	1.3	2.4	2.6	6.8	8.8	8.0	7.3	5.2	5.0	2.4	1.5	52.9
WILLISTON, ND	1.5	1.0	1.8	2.5	4.9	6.4	6.5	3.7	2.7	2.3	1.7	1.6	36.5
AKRON, OH	6.6	5.9	7.6	9.0	10.9	9.7	10.4	9.0	8.8	7.2	8.4	7.2	100.6
CLEVELAND, OH	6.9	5.9	7.4	8.9	9.3	8.7	8.8	8.9	9.7	7.8	9.2	7.9	99.4
COLUMBUS, OH	6.9	5.7	7.7	8.6	10.6	10.2	12.2	8.4	7.2	6.6	8.1	7.5	99.8
DAYTON, OH	6.9	5.7	8.5	10.4	11.8	10.6	10.4	7.6	8.4	7.4	8.6	7.9	104.3
MANSFIELD, OH	7.3	6.1	8.6	10.5	11.5	12.1	11.1	11.1	8.4	7.5	9.7	8.4	112.2
TOLEDO, OH	5.2	5.3	6.3	8.1	9.1	9.1	8.2	8.0	7.1	6.6	7.3	6.8	87.0
YOUNGSTOWN, OH	6.5	5.5	7.5	8.5	9.6	9.9	10.9	8.2	9.5	7.0	8.1	7.6	98.8
OKLAHOMA CITY, OK	3.5	4.0	7.8	7.8	11.8	12.5	7.4	8.3	10.3	9.4	5.0	4.8	92.8
TULSA, OK	4.5	5.8	9.0	10.1	14.8	13.2	8.6	8.7	11.7	10.4	8.1	6.3	111.1
ASTORIA, OR	25.9	18.3	18.9	13.2	8.4	6.5	2.6	2.9	5.4	15.2	28.3	25.1	170.8
BURNS, OR	3.0	2.6	2.8	2.4	3.1	1.9	1.0	0.9	1.1	2.0	3.0	3.9	27.7
EUGENE, OR	17.4	13.8	12.7	8.5	7.0	3.8	1.4	1.5	3.3	8.3	19.6	19.9	117.1
MEDFORD, OR	6.2	5.1	4.3	3.5	3.3	1.6	0.7	1.0	1.4	2.9	7.7	8.9	46.6
PENDLETON, OR	3.6	2.8	3.4	3.0	3.4	2.5	0.8	1.0	1.4	2.6	3.9	3.7	32.2
PORTLAND, OR	12.4	9.3	9.3	6.9	6.3	4.3	1.7	1.7	3.7	7.6	14.3	13.9	91.5
SALEM, OR	15.1	11.6	10.1	7.1	5.6	3.9	1.2	1.1	3.3	7.7	16.5	17.4	100.8
SEXTON SUMMIT, OR	13.2	10.2	9.8	6.6	5.6	2.2	0.8	1.0	2.0	6.4	13.6	17.9	89.3
ALLENTOWN, PA	7.7	6.9	8.6	9.0	10.5	10.9	12.6	9.4	11.7	9.9	8.9	9.1	115.2
ERIE, PA	7.5	6.1	7.5	8.5	8.7	9.6	9.0	8.8	11.7	10.3	10.0	9.5	107.1
HARRISBURG, PA	7.3	6.1	8.6	7.9	9.6	9.1	11.7	8.1	10.3	8.3	8.2	8.2	103.5
MIDDLETOWN/HARRISBURG INT	7.3	6.1	8.6	7.9	9.6	9.1	11.7	8.1	10.3	8.3	8.2	8.2	103.5
PHILADELPHIA, PA	7.7	6.7	9.6	9.0	9.4	8.7	11.0	8.9	9.6	8.1	7.6	9.0	105.5

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Average Rainfall Normals, 1981–2010 (centimeters)													
	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
PITTSBURGH, PA	6.9	6.1	7.5	7.9	10.0	10.9	9.7	8.8	7.9	5.8	8.2	7.2	97.0
AVOCA, PA	6.0	5.2	6.5	8.5	8.9	10.2	9.6	8.7	10.3	8.5	8.0	6.8	97.2
WILLIAMSPORT, PA	6.9	5.9	7.5	8.2	9.3	10.0	11.0	9.8	10.6	8.7	9.5	7.4	104.9
PROVIDENCE, RI	9.8	8.4	12.7	11.1	9.0	9.2	8.4	9.1	10.0	10.0	11.5	10.7	119.8
CHARLESTON AP, SC	9.4	7.5	9.4	7.4	7.7	14.4	16.6	18.2	15.5	9.5	6.2	7.9	129.6
CHARLESTON C.O., SC	7.5	6.4	8.4	6.4	5.5	11.8	13.7	17.0	14.6	9.3	5.6	6.6	112.8
COLUMBIA, SC	9.1	9.2	9.5	6.7	7.5	11.9	13.9	13.4	9.0	8.1	7.0	8.2	113.3
GREENVILLE-SPARTANBURG AP	9.7	10.1	11.5	8.5	9.6	9.7	12.2	11.4	8.7	8.7	9.4	10.4	119.9
ABERDEEN, SD	1.2	1.4	2.9	4.7	7.9	9.4	7.7	6.2	5.6	5.1	1.9	1.3	55.2
HURON, SD	1.3	1.5	3.7	5.9	7.9	10.0	7.4	6.2	6.2	4.5	2.2	1.3	58.2
RAPID CITY, SD	0.8	1.1	2.4	4.6	8.2	6.4	4.7	4.0	3.3	3.6	1.3	1.1	41.4
SIOUX FALLS, SD	1.4	1.5	4.5	7.6	8.6	10.0	7.8	7.7	7.0	5.5	3.5	1.8	67.0
BRISTOL-JHNSN CTY-KNGSPRT	8.6	8.8	8.7	8.5	9.7	9.9	11.9	8.8	7.6	5.3	7.9	8.6	104.2
CHATTANOOGA, TN	12.5	12.3	12.6	10.1	10.4	10.3	12.5	8.8	10.3	8.3	12.7	12.4	133.3
KNOXVILLE, TN	11.0	10.8	11.0	10.2	11.5	9.7	12.9	8.3	8.2	6.4	10.2	11.4	121.6
MEMPHIS, TN	10.1	11.2	13.1	14.0	13.3	9.2	11.7	7.3	7.8	10.1	13.9	14.6	136.3
NASHVILLE, TN	9.5	10.0	10.4	10.2	14.0	10.5	9.2	8.1	8.7	7.7	10.9	10.8	120.0
OAK RIDGE, TN	12.5	13.0	12.7	11.8	12.3	11.3	14.2	8.9	10.2	7.8	12.5	13.8	140.9
ABILENE, TX	2.6	3.5	4.4	4.2	8.1	9.0	4.7	6.6	5.7	7.6	3.6	3.1	63.0
AMARILLO, TX	1.8	1.4	3.5	3.6	5.8	8.0	7.2	7.4	4.9	4.2	2.0	1.8	51.7
AUSTIN/CITY, TX	5.6	5.1	7.0	5.3	11.3	11.0	4.8	6.0	7.6	9.9	7.5	6.1	87.2
AUSTIN/BERGSTROM, TX	5.7	6.0	6.4	5.8	6.8	11.1	6.2	4.1	6.3	10.0	7.5	5.7	81.7
BROWNSVILLE, TX	3.2	2.7	3.1	3.9	6.7	6.5	5.2	6.2	15.0	9.5	4.6	2.9	69.7
CORPUS CHRISTI, TX	3.9	4.9	4.8	4.7	7.8	8.5	7.1	7.4	12.6	9.2	5.0	4.6	80.7
DALLAS-FORT WORTH, TX	5.4	6.8	8.9	7.8	12.4	9.6	5.5	4.9	6.5	10.7	6.9	6.5	91.8
DALLAS-LOVE FIELD, TX	5.2	6.6	8.9	7.8	12.5	10.4	5.6	4.7	7.2	12.2	7.3	7.0	95.4
DEL RIO, TX	1.8	2.2	2.9	4.2	7.1	6.0	4.5	5.5	5.6	5.7	2.4	1.7	49.6

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Average Rainfall Normals, 1981–2010 (centimeters)													
	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
EL PASO, TX	1.0	1.2	0.7	0.6	1.2	2.4	3.9	5.1	3.8	1.5	1.2	2.0	24.7
GALVESTON, TX	10.7	6.5	8.0	7.7	11.0	14.5	9.7	11.2	15.3	14.0	11.5	8.9	128.9
HOUSTON, TX	10.7	8.1	7.7	8.9	11.5	14.1	12.0	11.0	13.4	13.9	12.1	10.4	133.8
LUBBOCK, TX	1.7	1.9	2.8	3.6	5.8	7.7	4.9	4.9	6.4	4.9	2.2	1.9	48.6
MIDLAND-ODESSA, TX	1.4	1.8	1.5	1.7	4.4	4.6	4.6	4.7	4.7	4.4	1.8	1.5	37.1
PORT ARTHUR, TX	13.4	9.1	9.0	8.2	13.3	18.0	15.1	13.7	15.2	14.2	11.2	13.4	153.6
SAN ANGELO, TX	2.4	3.4	3.8	3.6	7.2	6.6	3.0	5.7	6.2	6.9	2.9	2.2	54.0
SAN ANTONIO, TX	4.4	4.6	5.9	5.5	8.7	9.5	5.3	6.4	7.2	9.5	5.8	4.8	77.5
VICTORIA, TX	6.4	5.3	7.0	7.2	13.2	11.3	10.6	7.2	10.6	11.8	8.2	5.9	104.7
WACO, TX	5.4	6.7	8.0	6.8	10.9	8.7	4.5	5.2	7.8	9.9	7.2	7.0	88.1
WICHITA FALLS, TX	2.9	4.4	5.6	6.6	9.6	10.5	4.0	6.4	7.1	7.9	4.2	4.1	73.5
SALT LAKE CITY, UT	3.2	3.2	4.5	5.1	5.0	2.5	1.5	1.8	3.1	3.9	3.7	3.6	40.9
BURLINGTON, VT	5.2	4.5	5.6	7.2	8.8	9.4	10.6	9.9	9.2	9.1	8.0	6.0	93.5
LYNCHBURG, VA	8.0	7.4	9.1	8.4	9.5	9.2	11.1	8.3	9.9	7.9	8.7	8.2	105.6
NORFOLK, VA	8.6	7.9	9.3	8.7	8.7	10.8	13.1	14.0	12.1	8.7	8.0	8.3	118.2
RICHMOND, VA	7.7	7.0	10.3	8.3	9.6	10.0	11.5	11.8	10.5	7.6	8.2	8.3	110.7
ROANOKE, VA	7.4	7.3	8.8	8.6	10.3	9.7	10.3	9.0	9.9	7.3	8.6	7.5	104.8
OLYMPIA, WA	19.9	13.4	13.4	9.0	5.9	4.5	1.6	2.4	4.3	11.7	21.9	18.9	127.0
QUILLAYUTE, WA	37.1	26.3	27.5	19.9	13.0	8.9	5.0	6.3	9.7	26.6	39.4	33.0	252.8
SEATTLE C.O., WA	13.9	8.9	9.8	7.1	5.1	4.0	2.2	2.4	3.3	8.6	15.2	15.4	95.8
SEATTLE SEA-TAC AP, WA	14.1	8.9	9.4	6.9	4.9	4.0	1.8	2.2	3.8	8.8	16.7	13.6	95.2
SPOKANE, WA	4.5	3.4	4.1	3.3	4.1	3.2	1.6	1.5	1.7	3.0	5.8	5.8	42.1
WALLA WALLA, WA	6.4	4.5	5.8	4.9	5.4	3.3	1.5	1.4	1.9	4.3	7.3	6.3	53.0
YAKIMA, WA	2.9	2.0	1.6	1.4	1.5	1.6	0.6	0.7	0.9	1.4	2.7	3.9	21.0
BECKLEY, WV	7.1	7.0	9.1	8.5	11.8	10.2	12.8	8.8	7.6	6.5	7.5	7.6	104.6
CHARLESTON, WV	7.6	8.1	9.9	8.2	12.2	10.9	12.5	9.5	8.3	6.8	9.5	8.3	111.8
ELKINS, WV	8.7	8.1	10.0	9.0	12.1	11.7	12.3	10.8	9.7	7.3	8.7	8.7	117.1
HUNTINGTON, WV	7.5	7.8	9.9	8.7	11.9	9.9	11.6	9.5	7.1	7.1	8.7	8.4	108.2
GREEN BAY, WI	2.9	2.8	4.7	6.7	7.4	9.9	8.9	8.6	7.7	6.2	5.4	3.8	75.0
LA CROSSE, WI	2.8	2.7	5.2	8.5	8.9	11.0	10.8	10.9	9.0	5.5	5.1	3.5	84.0

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Average Rainfall Normals, 1981–2010 (centimeters)													
	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
MADISON, WI	3.1	3.7	5.6	8.6	9.0	11.5	10.6	10.8	8.0	6.1	6.1	4.4	87.6
MILWAUKEE, WI	4.5	4.2	5.8	9.0	8.6	9.9	9.3	10.1	8.1	6.7	6.9	5.2	88.3
CASPER, WY	1.3	1.4	2.1	3.3	5.1	4.1	3.6	2.2	2.7	2.8	1.9	1.2	31.8
CHEYENNE, WY	0.8	1.2	2.7	4.5	5.9	5.9	5.6	5.0	3.8	2.4	1.5	1.2	40.5
LANDER, WY	2.8	1.7	4.9	5.3	4.5	3.0	2.2	2.2	2.9	3.6	3.0	3.5	39.5
SHERIDAN, WY	1.4	1.4	2.5	4.1	6.0	5.4	3.0	1.8	3.6	3.6	1.8	1.4	36.0
GUAM, PC	12.6	11.5	7.0	9.1	10.9	18.0	30.8	43.6	36.0	30.0	23.3	15.2	248.0
JOHNSTON ISLAND, PC	4.9	3.4	5.4	4.7	2.6	2.3	3.4	5.2	6.9	9.3	12.4	7.0	67.2
KOROR, PC	28.2	24.2	21.0	20.8	31.8	45.7	46.0	35.4	30.7	30.6	30.2	30.3	375.0
KWAJALEIN MARSHALL IS, P	10.2	8.4	9.0	15.8	16.8	20.0	25.0	26.4	27.7	30.0	28.1	20.7	238.0
MAJURO MARSHALL IS, PC	21.0	19.4	19.2	24.5	25.0	27.8	30.3	29.0	30.8	33.7	33.6	29.4	323.6
PAGO PAGO AMER SAMOA, PC	36.8	32.2	29.6	28.0	27.0	14.9	16.4	16.0	19.4	25.7	28.7	36.9	311.5
POHNPEI CAROLINE IS, PC	33.6	25.5	35.9	45.1	46.6	40.1	40.9	37.6	37.8	38.8	38.1	40.4	460.3
CHUUK E CAROLINE IS, PC	25.8	18.4	22.4	31.0	29.8	31.0	31.5	34.2	32.6	29.0	28.0	28.0	341.7
WAKE ISLAND, PC	3.6	4.4	5.7	5.6	4.5	4.9	10.6	13.8	11.7	11.2	6.8	4.8	87.5
YAP W CAROLINE IS, PC	18.5	15.2	13.6	14.5	21.6	33.5	38.2	39.3	35.0	31.1	23.1	23.6	307.2
SAN JUAN, PR	9.6	6.1	5.0	11.9	15.0	11.2	12.9	13.9	14.7	14.2	16.1	12.8	143.1
Source: NOAA National Weather Service													

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Average Rainfall Normals, 1981 – 2010 (inches)													
	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
BIRMINGHAM AP, AL	4.84	4.53	5.23	4.38	4.99	4.38	4.8	3.93	3.9	3.44	4.85	4.45	53.72
HUNTSVILLE, AL	4.89	4.84	5.21	4.32	5.11	4.29	4.05	3.61	3.72	3.59	4.94	5.77	54.34
MOBILE, AL	5.67	4.81	6.43	4.57	5.3	6.37	6.46	6.13	5.31	4.11	5	5.12	65.28
MONTGOMERY, AL	4.65	5.28	5.95	4.02	3.54	4.07	5.24	3.96	3.97	2.92	4.61	4.86	53.07
ANCHORAGE, AK	0.73	0.72	0.6	0.47	0.72	0.97	1.83	3.25	2.99	2.03	1.16	1.11	16.58
ANNETTE, AK	10.73	7.31	8.05	6.77	5.56	4.88	4.65	6.96	9.79	13.92	12.29	10.72	101.63
BARROW, AK	0.13	0.14	0.09	0.16	0.18	0.32	0.98	1.05	0.72	0.41	0.21	0.14	4.53
BETHEL, AK	0.78	0.72	0.71	0.74	1.14	1.72	2.36	3.25	2.75	1.65	1.6	1.12	18.54
BETTLES, AK	0.81	0.85	0.58	0.6	0.88	1.4	2.36	2.64	1.91	1.04	0.91	0.92	14.9
BIG DELTA, AK	0.31	0.28	0.18	0.23	0.9	2.31	2.68	1.89	1.03	0.8	0.63	0.38	11.62
COLD BAY, AK	3.16	2.98	2.7	2.42	2.6	2.72	2.48	3.68	4.73	4.76	4.98	4.46	41.67
FAIRBANKS, AK	0.58	0.42	0.25	0.31	0.6	1.37	2.16	1.88	1.1	0.83	0.67	0.64	10.81
GULKANA, AK	0.46	0.51	0.3	0.24	0.65	1.4	1.81	1.8	1.58	1.01	0.72	0.78	11.26
HOMER, AK	2.63	1.71	1.65	1.07	0.82	0.82	1.55	2.34	3.31	2.57	2.79	3.08	24.34
JUNEAU, AK	5.35	4.13	3.78	2.94	3.4	3.24	4.6	5.73	8.64	8.63	5.99	5.84	62.27
KING SALMON, AK	1.02	0.76	0.7	0.97	1.25	1.65	2.3	2.95	3.19	2.08	1.39	1.23	19.49
KODIAK, AK	8.29	6.14	5.53	5.81	5.62	5.91	4.93	4.56	7.35	8.26	6.87	8.73	78
KOTZEBUE, AK	0.62	0.66	0.44	0.54	0.41	0.58	1.45	2.18	1.58	1.01	0.77	0.76	11
MCGRATH, AK	1.09	0.94	0.81	0.74	1.09	1.52	2.38	2.8	2.49	1.44	1.41	1.29	18
NOME, AK	0.94	0.93	0.65	0.76	0.86	0.98	2.11	3.22	2.45	1.61	1.22	1.08	16.81
ST. PAUL ISLAND, AK	1.58	1.3	1.07	1.08	1.13	1.35	1.85	3.07	2.99	3.11	2.89	2.25	23.67
TALKEETNA, AK	1.36	1.45	1.05	1.29	1.62	1.92	3.39	5.11	4.32	2.9	1.63	1.93	27.97
VALDEZ, AK	6.64	4.79	4.4	4.02	3.11	2.9	3.24	6.05	9.57	8.39	7.55	10.41	71.07
YAKUTAT, AK	13.66	10.86	11.04	9.19	8.21	6.39	7.88	14.07	21.11	21.98	14.45	16.28	155.12
FLAGSTAFF, AZ	2.05	2.16	2.12	1.15	0.63	0.36	2.61	3.11	2.38	1.66	1.76	1.87	21.86
PHOENIX, AZ	0.91	0.92	0.99	0.28	0.11	0.02	1.05	1	0.64	0.58	0.65	0.88	8.03
TUCSON, AZ	1.29	1.16	0.84	0.43	0.42	0.55	2.13	3.02	1.64	1.09	0.99	1.34	14.9
WINSLOW, AZ	0.52	0.46	0.54	0.26	0.33	0.18	1.04	1.2	0.88	0.53	0.51	0.56	7.01
YUMA, AZ	0.38	0.28	0.27	0.09	0.05	0.02	0.23	0.61	0.26	0.26	0.14	0.42	3.01
FORT SMITH, AR	2.81	2.76	3.85	4.3	5.47	4.28	3.3	2.59	4.05	4.32	4.44	3.29	45.46
LITTLE ROCK, AR	3.55	3.66	4.68	5.14	4.87	3.65	3.27	2.59	3.18	4.91	5.28	4.97	49.75
NORTH LITTLE ROCK, AR	3.42	3.66	4.77	4.79	4.96	3.31	3.81	2.8	3.31	4.8	5.39	5.01	50.03
BAKERSFIELD, CA	1.16	1.24	1.21	0.52	0.18	0.08	0	0.04	0.08	0.3	0.64	1.02	6.47
BISHOP, CA	1.05	0.85	0.53	0.26	0.19	0.19	0.17	0.13	0.19	0.3	0.52	0.8	5.18

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Average Rainfall Normals, 1981 – 2010 (inches)													
	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
EUREKA, CA	6.5	5.63	5.3	3.32	1.78	0.75	0.18	0.31	0.59	2.24	5.61	8.12	40.33
FRESNO, CA	2.19	2.03	2.03	0.95	0.43	0.21	0.01	0.01	0.17	0.63	1.07	1.77	11.5
LONG BEACH, CA	2.6	3.09	1.87	0.6	0.21	0.07	0.03	0.03	0.18	0.63	1	1.95	12.26
LOS ANGELES AP, CA	2.71	3.25	1.85	0.7	0.22	0.08	0.03	0.05	0.21	0.56	1.11	2.05	12.82
LOS ANGELES C.O., CA	3.12	3.8	2.43	0.91	0.26	0.09	0.01	0.04	0.24	0.66	1.04	2.33	14.93
REDDING, CA	6.16	9.41	7.75	3.76	2.31	1.26	0.43	0.48	0.87	2.91	5.15	7.26	47.75
SACRAMENTO, CA	3.64	3.47	2.75	1.15	0.68	0.21	0	0.05	0.29	0.95	2.08	3.25	18.52
SAN DIEGO, CA	1.98	2.27	1.81	0.78	0.12	0.07	0.03	0.02	0.15	0.57	1.01	1.53	10.34
SAN FRANCISCO AP, CA	4.19	4.06	2.96	1.29	0.47	0.11	0	0.04	0.17	0.95	2.38	4.03	20.65
SAN FRANCISCO C.O., CA	4.5	4.46	3.26	1.46	0.7	0.16	0	0.06	0.21	1.12	3.16	4.56	23.65
SANTA BARBARA, CA	3.5	3.96	3.18	1	0.34	0.07	0.03	0.12	0.26	0.81	1.55	2.94	17.76
SANTA MARIA, CA	2.75	2.99	2.64	0.98	0.31	0.04	0.03	0.02	0.14	0.6	1.33	2.12	13.95
STOCKTON, CA	2.74	2.54	2.16	0.98	0.53	0.08	0	0.01	0.29	0.82	1.69	2.22	14.06
ALAMOSA, CO	0.26	0.26	0.53	0.59	0.58	0.49	0.97	1.27	0.91	0.68	0.42	0.35	7.31
COLORADO SPRINGS, CO	0.32	0.34	1	1.42	2.03	2.5	2.84	3.34	1.19	0.82	0.4	0.34	16.54
DENVER, CO	0.41	0.37	0.92	1.71	2.12	1.98	2.16	1.69	0.96	1.02	0.61	0.35	14.3
GRAND JUNCTION, CO	0.58	0.54	0.92	0.91	0.88	0.46	0.61	0.95	1.19	1.06	0.73	0.59	9.42
PUEBLO, CO	0.35	0.3	0.93	1.4	1.51	1.36	2.06	2.32	0.77	0.72	0.47	0.38	12.57
BRIDGEPORT, CT	3.1	2.79	4.05	4.13	3.8	3.61	3.46	3.96	3.48	3.64	3.39	3.33	42.74
HARTFORD, CT	3.15	2.65	3.57	3.88	3.89	3.99	4	3.66	3.48	4.14	3.84	3.35	43.6
WILMINGTON, DE	3.01	2.68	3.92	3.5	3.95	3.88	4.57	3.25	4.32	3.42	3.1	3.48	43.08
WASHINGTON DULLES AP, DC	2.68	2.74	3.38	3.47	4.55	3.98	3.67	3.53	3.92	3.25	3.41	2.96	41.54
WASHINGTON NAT'L AP, DC	2.81	2.62	3.48	3.06	3.99	3.78	3.73	2.93	3.72	3.4	3.17	3.05	39.74
APALACHICOLA, FL	4.4	4.15	5.26	3.07	2.5	5.27	7.07	8.22	6.73	4.2	3.52	3.31	57.7
DAYTONA BEACH, FL	2.74	2.78	4.24	2.18	3.13	5.83	5.83	6.4	6.96	4.21	2.69	2.63	49.62
FORT MYERS, FL	1.94	2.15	2.88	2.18	2.65	10.09	9.04	10.14	8.31	2.88	1.96	1.71	55.93
GAINESVILLE, FL	3.33	3.2	4.33	2.67	2.48	7.12	6.07	6.39	4.42	2.88	2.06	2.38	47.33
JACKSONVILLE, FL	3.3	3.19	3.95	2.64	2.48	6.45	6.55	6.8	8.19	3.93	2.11	2.8	52.39
KEY WEST, FL	2.37	1.73	2	2.27	3.51	5.16	4.12	7.34	8.96	5.05	2.14	2.21	46.86
MIAMI, FL	1.62	2.25	3	3.14	5.34	9.67	6.5	8.88	9.86	6.33	3.27	2.04	61.9
ORLANDO, FL	2.74	2.83	3.79	2.49	3.3	8.74	7.1	7.82	6.02	3.29	2.42	2.63	53.17
PENSACOLA, FL	4.52	5.11	5.47	4.04	4.08	5.7	7.4	5.78	6.16	4.94	3.85	4.15	61.2

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Average Rainfall Normals, 1981 – 2010 (inches)													
	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
TALLAHASSEE, FL	4.34	4.85	5.94	3.06	3.47	7.73	7.17	7.35	4.69	3.23	3.5	3.9	59.23
TAMPA, FL	2.23	2.81	3.03	2.03	2.1	6.68	7.07	7.77	6.3	2.26	1.55	2.47	46.3
VERO BEACH, FL	2.5	2.67	4.12	2.72	3.36	6.67	5.63	7.03	6.79	4.91	3.28	2.19	51.87
WEST PALM BEACH, FL	3.13	2.82	4.59	3.66	4.51	8.3	5.76	7.95	8.35	5.13	4.75	3.38	62.33
ATHENS, GA	4.05	4.48	4.43	3.15	3	4.18	4.47	3.53	3.94	3.55	3.82	3.73	46.33
ATLANTA, GA	4.2	4.67	4.81	3.36	3.67	3.95	5.27	3.9	4.47	3.41	4.1	3.9	49.71
AUGUSTA, GA	4.21	4.03	4.31	2.95	3.18	4.29	5.27	4.92	3.37	3.23	3.17	3.62	46.55
COLUMBUS, GA	3.85	4.44	5.46	3.55	3.19	3.72	4.76	3.77	3.06	2.58	4.1	4.27	46.75
MACON, GA	4.24	4.36	4.55	2.96	2.72	4.06	4.95	4.1	3.59	2.79	3.32	4.04	45.68
SAVANNAH, GA	3.69	2.79	3.73	3.07	2.98	5.95	5.6	6.56	4.58	3.69	2.37	2.95	47.96
HILO, HI	12.62	12.44	15.26	15.55	8.85	8.85	13.67	9.38	12.53	12.44	16.31	18.89	156.79
HONOLULU, HI	2.31	1.99	2.02	0.63	0.62	0.26	0.51	0.56	0.7	1.84	2.42	3.24	17.1
KAHULUI, HI	2.87	1.89	2.45	1.55	0.74	0.2	0.5	0.5	0.38	1.2	2.2	3.35	17.83
LIHUE, HI	3.75	3.16	4.61	2.25	2.07	1.61	1.87	2.13	2.12	3.82	4.46	5.2	37.05
BOISE, ID	1.24	0.99	1.39	1.23	1.39	0.69	0.33	0.24	0.58	0.75	1.35	1.55	11.73
LEWISTON, ID	1.08	0.78	1.15	1.32	1.61	1.24	0.66	0.69	0.67	0.96	1.18	0.97	12.31
POCATELLO, ID	0.99	0.97	1.26	1.15	1.46	0.99	0.64	0.61	0.84	0.87	1.11	1.24	12.13
CHICAGO, IL	1.73	1.79	2.5	3.38	3.68	3.45	3.7	4.9	3.21	3.15	3.15	2.25	36.89
MOLINE, IL	1.49	1.6	2.86	3.59	4.32	4.49	4.29	4.52	3.09	2.97	2.56	2.18	37.96
PEORIA, IL	1.78	1.79	2.8	3.63	4.33	3.53	3.85	3.24	3.15	2.84	3.13	2.42	36.49
ROCKFORD, IL	1.37	1.41	2.32	3.35	4.02	4.65	3.95	4.59	3.35	2.67	2.58	1.98	36.24
SPRINGFIELD, IL	1.82	1.81	2.63	3.51	4.24	4.46	3.94	3.24	2.9	3.15	3.21	2.52	37.43
EVANSVILLE, IN	3.1	3.17	4.24	4.37	5.36	3.78	3.92	2.98	3.05	3.25	4.33	3.76	45.31
FORT WAYNE, IN	2.26	2.04	2.71	3.52	4.27	4.16	4.24	3.64	2.8	2.84	3.09	2.77	38.34
INDIANAPOLIS, IN	2.21	2.13	3.3	3.9	5.27	4.39	4.26	3.19	2.25	3.11	3.7	3.08	40.79
SOUTH BEND, IN	2.29	1.95	2.42	3.23	3.83	3.79	4	3.76	3.53	3.32	3.27	2.61	38
DES MOINES, IA	0.92	1.23	2.23	3.71	4.66	4.7	4.5	4.74	3.12	2.52	2.18	1.32	35.83
DUBUQUE, IA	1.17	1.44	2.41	3.66	4.19	4.4	4.31	4.4	3.46	2.66	2.35	1.84	36.29
SIOUX CITY, IA	0.62	0.67	2	2.95	3.74	3.89	3.44	3.23	2.96	2.13	1.31	0.8	27.74
WATERLOO, IA	0.83	0.99	2.06	3.71	4.53	4.98	4.91	4.27	2.63	2.48	2.01	1.2	34.6
CONCORDIA, KS	0.58	0.79	2.01	2.45	4.16	4.05	3.92	3.14	2.91	1.92	1.11	0.85	27.89
DODGE CITY, KS	0.58	0.68	1.59	1.82	2.85	3.24	3.08	2.75	1.67	1.74	0.76	0.84	21.6
GOODLAND, KS	0.38	0.49	1.07	1.59	2.95	3.25	3.47	2.7	1.22	1.37	0.71	0.46	19.66
TOPEKA, KS	0.86	1.32	2.49	3.53	4.91	5.4	3.82	4.24	3.66	3.03	1.85	1.35	36.46
WICHITA, KS	0.83	1.18	2.69	2.59	4.57	5.2	3.32	3.71	3.14	2.78	1.43	1.2	32.64

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Average Rainfall Normals, 1981 – 2010 (inches)													
	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
GREATER CINCINNATI AP, OH	2.82	2.54	3.88	3.86	5.03	4.05	3.86	3.61	2.83	3.11	3.2	3.15	41.94
JACKSON, KY	3.61	3.75	4.12	3.83	5.2	4.7	4.65	3.69	3.46	3.19	3.96	4.18	48.34
LEXINGTON, KY	3.2	3.2	4.07	3.6	5.26	4.44	4.65	3.25	2.91	3.13	3.53	3.93	45.17
LOUISVILLE, KY	3.38	3.18	4.16	4.08	5.12	4.14	4.17	3.31	3.16	3.22	3.61	4.01	45.54
PADUCAH, KY	3.68	3.91	3.93	4.76	4.94	4.06	4.44	2.76	3.75	3.96	4.3	4.59	49.08
BATON ROUGE, LA	5.72	5.04	4.41	4.46	4.89	6.41	4.96	5.82	4.54	4.7	4.1	5.6	60.65
LAKE CHARLES, LA	5.23	3.46	3.66	3.33	5.2	6.85	5.63	4.86	5.26	4.9	4.43	4.68	57.49
NEW ORLEANS, LA	5.15	5.3	4.55	4.61	4.63	8.06	5.93	5.98	4.97	3.54	4.49	5.24	62.45
SHREVEPORT, LA	4.19	4.77	4.35	4.05	4.45	4.97	3.49	2.61	3.36	5.05	4.74	4.92	50.95
CARIBOU, ME	2.71	2.21	2.51	2.66	3.33	3.48	4.08	3.76	3.32	3.53	3.63	3.27	38.49
PORTLAND, ME	3.38	3.25	4.24	4.32	4.01	3.79	3.61	3.14	3.69	4.87	4.93	4.02	47.25
BALTIMORE, MD	3.05	2.9	3.9	3.19	3.99	3.46	4.07	3.29	4.03	3.33	3.3	3.37	41.88
BOSTON, MA	3.36	3.25	4.32	3.74	3.49	3.68	3.43	3.35	3.44	3.94	3.99	3.78	43.77
WORCESTER, MA	3.49	3.23	4.21	4.11	4.19	4.19	4.23	3.71	3.93	4.68	4.28	3.82	48.07
ALPENA, MI	1.66	1.32	1.86	2.39	2.67	2.62	3.03	3.23	2.92	2.61	2.1	1.75	28.16
DETROIT, MI	1.4	1.7	2.02	2.78	3.07	3.25	3.03	3.16	3.39	2.72	2.84	1.97	31.33
FLINT, MI	1.63	1.48	1.91	2.89	3.08	3.07	3.32	3.18	3.75	2.47	2.67	1.92	31.37
GRAND RAPIDS, MI	2.09	1.79	2.37	3.35	3.98	3.77	3.78	3.59	4.28	3.26	3.51	2.5	38.27
HOUGHTON LAKE, MI	1.51	1.21	1.84	2.48	2.82	3.1	2.76	3.4	3.1	2.56	2.32	1.65	28.75
LANSING, MI	1.65	1.47	2.06	3.03	3.36	3.45	2.84	3.23	3.5	2.53	2.78	1.87	31.77
MARQUETTE, MI	2.41	2.14	3.03	3.01	3.05	2.84	2.84	3.05	3.72	3.84	3.18	2.57	35.68
MUSKEGON, MI	2.03	1.83	2.25	2.91	3.25	2.55	2.37	3.39	3.89	3.11	3.36	2.55	33.49
SAULT STE. MARIE, MI	2.19	1.34	1.95	2.39	2.57	2.7	2.86	3.17	3.82	3.8	3.37	2.79	32.95
DULUTH, MN	0.96	0.81	1.49	2.43	3.23	4.23	3.85	3.7	4.11	2.85	2.09	1.21	30.96
INTERNATIONAL FALLS, MN	0.62	0.57	0.95	1.53	2.86	3.92	3.7	2.81	2.99	2.08	1.38	0.81	24.22
MINNEAPOLIS-ST. PAUL, MN	0.9	0.77	1.89	2.66	3.36	4.25	4.04	4.3	3.08	2.43	1.77	1.16	30.61
ROCHESTER, MN	0.86	0.83	1.88	3.24	3.63	4.68	4.55	4.52	3.45	2.24	1.91	1.23	33.02
SAINT CLOUD, MN	0.65	0.59	1.55	2.57	2.95	4.17	3.31	3.79	3.46	2.49	1.38	0.82	27.73
JACKSON, MS	5.01	4.39	5.1	5.11	4.85	4.13	4.55	4.01	3.22	3.99	4.77	5.19	54.32
MERIDIAN, MS	5.13	5.6	5.42	4.78	4.5	4.4	5.14	3.99	3.43	3.76	4.95	5.06	56.16
TUPELO, MS	4.48	4.96	4.82	4.78	5.56	4.52	3.9	3.45	3.44	4.12	4.7	6.28	55.01
COLUMBIA, MO	1.92	2.25	2.91	4.49	4.98	4.47	4.37	4.36	3.87	3.31	3.25	2.44	42.62
KANSAS CITY, MO	1.14	1.48	2.15	3.71	5.13	5.52	3.97	4.39	4.16	3.52	2.14	1.75	39.06

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Average Rainfall Normals, 1981 – 2010 (inches)													
	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
ST. LOUIS, MO	2.4	2.24	3.32	3.69	4.72	4.28	4.11	2.99	3.13	3.33	3.91	2.84	40.96
SPRINGFIELD, MO	2.47	2.52	3.62	4.32	5.1	4.85	3.68	3.55	4.61	3.59	4.22	3.04	45.57
BILLINGS, MT	0.48	0.48	1.06	1.66	2.18	2.12	1.32	0.75	1.3	1.18	0.63	0.5	13.66
GLASGOW, MT	0.37	0.26	0.42	0.85	1.92	2.33	1.78	1.24	0.94	0.75	0.4	0.4	11.66
GREAT FALLS, MT	0.51	0.47	0.91	1.42	2.42	2.53	1.5	1.57	1.42	0.86	0.59	0.55	14.75
HAVRE, TX	0.33	0.28	0.54	0.84	1.74	2.19	1.64	1.11	1.12	0.58	0.43	0.4	11.2
HELENA, MT	0.36	0.3	0.59	0.98	1.87	2.06	1.19	1.2	1.1	0.68	0.49	0.4	11.22
KALISPELL, MT	1.33	0.97	1.09	1.24	1.98	2.56	1.45	0.99	1.38	1.01	1.43	1.56	16.99
MISSOULA, MT	0.85	0.7	1	1.22	2.01	2.07	0.99	1.19	1.17	0.88	1.01	1.04	14.13
GRAND ISLAND, NE	0.53	0.68	1.8	2.53	4.41	4.3	3.4	3.12	2.23	1.86	1.17	0.63	26.66
LINCOLN, NE	0.63	0.76	2.09	2.57	4.51	4.48	3.57	3.22	3.04	2.04	1.41	0.93	29.25
NORFOLK, NE	0.59	0.76	1.77	2.65	3.93	4.26	3.32	3.25	2.69	2.07	1.37	0.75	27.41
NORTH PLATTE, NE	0.34	0.5	1.05	2.27	3.28	3.42	3.07	2.29	1.41	1.55	0.64	0.41	20.23
OMAHA EPPLEY AP, NE	0.72	0.85	1.99	2.96	4.76	4.18	3.83	3.82	2.68	2.15	1.64	1.04	30.62
OMAHA (NORTH), NE	0.7	0.86	2.12	3.44	4.7	4.12	3.95	3.53	2.86	2.42	1.49	1.02	31.21
SCOTTSBLUFF, NE	0.41	0.6	1	1.83	2.48	2.85	1.83	1.3	1.18	1.14	0.66	0.51	15.79
VALENTINE, NE	0.26	0.48	1.07	2.22	3.13	3.56	3.21	2.18	1.64	1.25	0.65	0.37	20.02
ELKO, NV	1.12	0.84	1	0.97	0.96	0.65	0.37	0.37	0.57	0.75	1.11	1.2	9.91
ELY, NV	0.7	0.75	0.93	0.95	1.1	0.67	0.64	0.9	0.83	1	0.7	0.59	9.76
LAS VEGAS, NV	0.54	0.76	0.44	0.15	0.12	0.07	0.4	0.33	0.25	0.27	0.36	0.5	4.19
RENO, NV	1.03	1.02	0.76	0.47	0.49	0.51	0.18	0.23	0.35	0.51	0.82	1.03	7.4
WINNEMUCCA, NV	0.87	0.66	0.83	0.89	1.12	0.56	0.25	0.18	0.44	0.67	0.88	0.93	8.28
CONCORD, NH	2.7	2.62	3.27	3.41	3.66	3.69	3.74	3.18	3.38	4.04	3.72	3.2	40.61
MT. WASHINGTON, NH	6.44	6.77	7.67	7.44	8.18	8.4	8.77	8.32	8.03	9.27	9.85	7.73	96.87
ATLANTIC CITY AP, NJ	3.22	2.87	4.21	3.63	3.35	3.11	3.72	4.11	3.15	3.42	3.27	3.69	41.75
ATLANTIC CITY C.O., NJ	3.08	2.87	4.02	3.39	3.22	2.68	3.31	3.92	3.08	3.47	3.35	3.62	40.01
NEWARK, NJ	3.54	2.88	4.18	4.2	4.09	4.02	4.76	3.7	3.82	3.6	3.65	3.81	46.25
ALBUQUERQUE, NM	0.38	0.48	0.57	0.61	0.5	0.66	1.5	1.58	1.08	1.02	0.57	0.5	9.45
CLAYTON, NM	0.28	0.34	0.95	0.94	1.96	2.13	2.66	2.94	1.67	1.11	0.45	0.36	15.79
ROSWELL, NM	0.38	0.42	0.51	0.61	1.25	1.73	2.06	1.97	1.53	1.23	0.58	0.64	12.91
ALBANY, NY	2.59	2.2	3.21	3.17	3.61	3.79	4.12	3.46	3.3	3.68	3.29	2.93	39.35
BINGHAMTON, NY	2.45	2.31	2.99	3.43	3.57	4.31	3.7	3.45	3.63	3.33	3.3	2.83	39.3
BUFFALO, NY	3.18	2.49	2.87	3.01	3.46	3.66	3.23	3.26	3.9	3.52	4.01	3.89	40.48
ISLIP, NY	3.64	3.26	4.44	4.34	3.78	4.27	3.43	3.98	3.58	3.79	3.67	4.06	46.24

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Average Rainfall Normals, 1981 – 2010 (inches)													
	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
NEW YORK C. PARK, NY	3.65	3.09	4.36	4.5	4.19	4.41	4.6	4.44	4.28	4.4	4.02	4	49.94
NEW YORK (JFK AP), NY	3.16	2.59	3.78	3.87	3.94	3.86	4.08	3.68	3.5	3.62	3.3	3.39	42.77
NEW YORK (LAGUARDIA AP),	3.17	2.76	3.97	4	3.79	3.94	4.5	4.12	3.73	3.78	3.41	3.56	44.73
ROCHESTER, NY	2.41	1.95	2.5	2.73	2.87	3.34	3.33	3.47	3.38	2.72	2.94	2.63	34.27
SYRACUSE, NY	2.5	2.07	2.95	3.19	3.22	3.31	3.78	3.57	3.69	3.44	3.53	3.22	38.47
ASHEVILLE, NC	3.49	3.45	4.09	3.61	3.86	5.04	5.38	4.41	3.97	2.85	4.34	3.65	48.14
CAPE HATTERAS, NC	5.24	4.02	4.77	3.64	3.57	4.03	4.99	6.93	6.25	5.38	4.95	4.27	58.04
CHARLOTTE, NC	3.41	3.32	4.01	3.04	3.18	3.74	3.68	4.22	3.24	3.4	3.14	3.25	41.63
GREENSBORO-WNSTN-SALM-HGH	3.06	2.96	3.73	3.57	3.38	3.73	4.48	3.88	4.19	3.13	3.11	2.98	42.2
RALEIGH, NC	3.5	3.23	4.11	2.92	3.27	3.52	4.73	4.26	4.36	3.25	3.12	3.07	43.34
WILMINGTON, NC	3.76	3.62	4.21	2.82	4.49	5.18	7.48	7.41	7.84	3.89	3.29	3.62	57.61
BISMARCK, ND	0.43	0.51	0.87	1.26	2.4	3.17	2.89	2.28	1.59	1.25	0.71	0.49	17.85
FARGO, ND	0.7	0.61	1.3	1.36	2.81	3.9	2.79	2.56	2.57	2.15	1	0.83	22.58
GRAND FORKS, ND	0.55	0.52	0.96	1.01	2.68	3.48	3.15	2.88	2.05	1.97	0.95	0.61	20.81
WILLISTON, ND	0.59	0.39	0.71	1	1.92	2.52	2.54	1.45	1.06	0.92	0.65	0.62	14.37
AKRON, OH	2.61	2.31	2.98	3.55	4.28	3.83	4.08	3.56	3.45	2.83	3.3	2.84	39.62
CLEVELAND, OH	2.72	2.34	2.93	3.49	3.66	3.43	3.46	3.51	3.81	3.07	3.62	3.1	39.14
COLUMBUS, OH	2.73	2.25	3.02	3.4	4.17	4.01	4.79	3.32	2.84	2.61	3.2	2.97	39.31
DAYTON, OH	2.71	2.24	3.34	4.09	4.66	4.17	4.11	2.99	3.3	2.93	3.39	3.12	41.05
MANSFIELD, OH	2.87	2.39	3.39	4.14	4.54	4.75	4.38	4.37	3.32	2.94	3.81	3.29	44.19
TOLEDO, OH	2.05	2.07	2.48	3.19	3.58	3.57	3.23	3.15	2.78	2.6	2.86	2.68	34.24
YOUNGSTOWN, OH	2.55	2.15	2.94	3.36	3.79	3.88	4.31	3.24	3.75	2.77	3.18	2.99	38.91
OKLAHOMA CITY, OK	1.39	1.58	3.06	3.07	4.65	4.93	2.93	3.28	4.06	3.71	1.98	1.88	36.52
TULSA, OK	1.78	2.28	3.53	3.96	5.81	5.2	3.37	3.41	4.62	4.11	3.17	2.49	43.73
ASTORIA, OR	10.2	7.19	7.45	5.2	3.32	2.55	1.03	1.16	2.14	5.98	11.15	9.89	67.26
BURNS, OR	1.19	1.02	1.09	0.93	1.23	0.76	0.4	0.36	0.44	0.78	1.17	1.55	10.92
EUGENE, OR	6.87	5.43	4.99	3.33	2.74	1.5	0.54	0.61	1.29	3.25	7.72	7.83	46.1
MEDFORD, OR	2.43	2.01	1.71	1.38	1.31	0.62	0.28	0.4	0.57	1.13	3.02	3.49	18.35
PENDLETON, OR	1.43	1.11	1.32	1.2	1.35	0.98	0.32	0.38	0.57	1.01	1.52	1.47	12.66
PORTLAND, OR	4.88	3.66	3.68	2.73	2.47	1.7	0.65	0.67	1.47	3	5.63	5.49	36.03
SALEM, OR	5.96	4.56	3.99	2.81	2.22	1.55	0.46	0.45	1.28	3.03	6.5	6.86	39.67
SEXTON SUMMIT, OR	5.19	4	3.87	2.58	2.22	0.88	0.33	0.4	0.78	2.5	5.37	7.04	35.16
ALLENTOWN, PA	3.03	2.7	3.39	3.56	4.14	4.31	4.95	3.69	4.62	3.88	3.5	3.58	45.35

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Average Rainfall Normals, 1981 – 2010 (inches)													
	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
ERIE, PA	2.95	2.39	2.95	3.33	3.44	3.76	3.54	3.47	4.61	4.05	3.93	3.74	42.16
HARRISBURG, PA	2.88	2.39	3.37	3.1	3.79	3.6	4.61	3.2	4.07	3.27	3.23	3.23	40.74
MIDDLETOWN/HARRISBURG INT	2.88	2.39	3.37	3.1	3.79	3.6	4.61	3.2	4.07	3.27	3.23	3.23	40.74
PHILADELPHIA, PA	3.03	2.65	3.79	3.56	3.71	3.43	4.35	3.5	3.78	3.18	2.99	3.56	41.53
PITTSBURGH, PA	2.7	2.39	2.95	3.11	3.95	4.3	3.83	3.48	3.11	2.29	3.23	2.85	38.19
AVOCA, PA	2.37	2.03	2.55	3.33	3.52	4.03	3.79	3.41	4.07	3.34	3.14	2.68	38.26
WILLIAMSPORT, PA	2.7	2.34	2.97	3.24	3.66	3.92	4.34	3.86	4.16	3.42	3.74	2.93	41.28
PROVIDENCE, RI	3.86	3.29	5.01	4.36	3.55	3.64	3.29	3.6	3.92	3.93	4.51	4.22	47.18
CHARLESTON AP, SC	3.71	2.96	3.71	2.91	3.02	5.65	6.53	7.15	6.1	3.75	2.43	3.11	51.03
CHARLESTON C.O., SC	2.94	2.51	3.3	2.53	2.16	4.65	5.4	6.71	5.76	3.67	2.19	2.6	44.42
COLUMBIA, SC	3.58	3.61	3.73	2.62	2.97	4.69	5.46	5.26	3.54	3.17	2.74	3.22	44.59
GREENVILLE-SPARTANBURG AP	3.82	3.97	4.52	3.36	3.76	3.8	4.8	4.48	3.43	3.44	3.7	4.11	47.19
ABERDEEN, SD	0.47	0.55	1.16	1.85	3.11	3.7	3.02	2.43	2.19	1.99	0.73	0.52	21.72
HURON, SD	0.5	0.6	1.46	2.31	3.11	3.93	2.92	2.43	2.46	1.79	0.87	0.52	22.9
RAPID CITY, SD	0.3	0.44	0.93	1.8	3.22	2.53	1.85	1.56	1.29	1.42	0.53	0.42	16.29
SIOUX FALLS, SD	0.56	0.6	1.76	3.01	3.4	3.92	3.09	3.05	2.77	2.17	1.36	0.69	26.38
BRISTOL-JHNSN CTY-KNGSPRT	3.37	3.45	3.44	3.33	3.8	3.9	4.69	3.47	2.99	2.1	3.1	3.37	41.01
CHATTANOOGA, TN	4.91	4.84	4.98	3.99	4.1	4.05	4.91	3.48	4.04	3.28	5	4.9	52.48
KNOXVILLE, TN	4.32	4.26	4.34	4.01	4.51	3.81	5.08	3.27	3.24	2.51	4.01	4.5	47.86
MEMPHIS, TN	3.98	4.39	5.16	5.5	5.25	3.63	4.59	2.88	3.09	3.98	5.49	5.74	53.68
NASHVILLE, TN	3.75	3.94	4.11	4	5.5	4.14	3.64	3.17	3.41	3.04	4.31	4.24	47.25
OAK RIDGE, TN	4.94	5.1	5	4.65	4.84	4.44	5.59	3.5	4.01	3.06	4.92	5.42	55.47
ABILENE, TX	1.02	1.36	1.74	1.64	3.18	3.56	1.87	2.59	2.24	2.98	1.41	1.23	24.82
AMARILLO, TX	0.72	0.56	1.39	1.4	2.29	3.16	2.84	2.91	1.92	1.66	0.8	0.71	20.36
AUSTIN/CITY, TX	2.22	2.02	2.76	2.09	4.44	4.33	1.88	2.35	2.99	3.88	2.96	2.4	34.32
AUSTIN/BERGSTROM, TX	2.23	2.37	2.51	2.28	2.66	4.38	2.45	1.63	2.49	3.95	2.95	2.25	32.15
BROWNSVILLE, TX	1.27	1.08	1.23	1.54	2.64	2.57	2.04	2.44	5.92	3.74	1.82	1.15	27.44
CORPUS CHRISTI, TX	1.54	1.93	1.89	1.84	3.07	3.36	2.79	2.92	4.98	3.64	1.97	1.83	31.76
DALLAS-FORT WORTH, TX	2.13	2.66	3.49	3.07	4.9	3.79	2.16	1.91	2.55	4.22	2.71	2.55	36.14
DALLAS-LOVE FIELD, TX	2.06	2.59	3.49	3.07	4.92	4.11	2.21	1.87	2.84	4.79	2.88	2.74	37.57
DEL RIO, TX	0.72	0.88	1.14	1.65	2.81	2.35	1.78	2.18	2.2	2.23	0.93	0.65	19.52

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Average Rainfall Normals, 1981 – 2010 (inches)													
	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
EL PASO, TX	0.4	0.46	0.26	0.23	0.47	0.94	1.55	2.01	1.51	0.61	0.49	0.78	9.71
GALVESTON, TX	4.2	2.57	3.16	3.05	4.32	5.69	3.8	4.39	6.03	5.52	4.51	3.52	50.76
HOUSTON, TX	4.22	3.18	3.03	3.52	4.54	5.55	4.71	4.35	5.26	5.46	4.78	4.09	52.69
LUBBOCK, TX	0.65	0.75	1.1	1.41	2.3	3.04	1.91	1.91	2.51	1.93	0.85	0.76	19.12
MIDLAND-ODESSA, TX	0.56	0.71	0.6	0.65	1.74	1.8	1.82	1.84	1.86	1.73	0.69	0.6	14.6
PORT ARTHUR, TX	5.26	3.58	3.53	3.21	5.23	7.09	5.95	5.38	5.97	5.58	4.4	5.29	60.47
SAN ANGELO, TX	0.93	1.35	1.5	1.42	2.82	2.59	1.2	2.26	2.46	2.73	1.14	0.85	21.25
SAN ANTONIO, TX	1.73	1.82	2.31	2.15	3.43	3.74	2.07	2.53	2.82	3.75	2.28	1.88	30.51
VICTORIA, TX	2.52	2.08	2.77	2.82	5.19	4.46	4.18	2.85	4.16	4.64	3.24	2.31	41.22
WACO, TX	2.12	2.63	3.15	2.69	4.3	3.43	1.79	2.05	3.06	3.9	2.82	2.75	34.69
WICHITA FALLS, TX	1.14	1.75	2.2	2.61	3.79	4.15	1.59	2.5	2.81	3.11	1.65	1.62	28.92
SALT LAKE CITY, UT	1.25	1.25	1.79	1.99	1.95	0.98	0.61	0.69	1.21	1.52	1.45	1.41	16.1
BURLINGTON, VT	2.06	1.76	2.22	2.82	3.45	3.69	4.16	3.91	3.64	3.6	3.13	2.38	36.82
LYNCHBURG, VA	3.14	2.93	3.58	3.31	3.73	3.62	4.36	3.26	3.88	3.11	3.41	3.24	41.57
NORFOLK, VA	3.4	3.12	3.68	3.41	3.41	4.26	5.14	5.52	4.76	3.42	3.15	3.26	46.53
RICHMOND, VA	3.04	2.76	4.04	3.27	3.78	3.93	4.51	4.66	4.13	2.98	3.24	3.26	43.6
ROANOKE, VA	2.92	2.89	3.46	3.37	4.06	3.83	4.04	3.56	3.89	2.89	3.4	2.94	41.25
OLYMPIA, WA	7.84	5.27	5.29	3.54	2.33	1.76	0.63	0.94	1.71	4.6	8.63	7.46	50
QUILLAYUTE, WA	14.61	10.35	10.83	7.85	5.11	3.5	1.98	2.49	3.82	10.49	15.52	12.99	99.54
SEATTLE C.O., WA	5.47	3.52	3.85	2.79	2.01	1.57	0.85	0.94	1.3	3.38	5.98	6.06	37.72
SEATTLE SEA-TAC AP, WA	5.57	3.5	3.72	2.71	1.94	1.57	0.7	0.88	1.5	3.48	6.57	5.35	37.49
SPOKANE, WA	1.79	1.33	1.61	1.28	1.62	1.25	0.64	0.59	0.67	1.18	2.3	2.3	16.56
WALLA WALLA, WA	2.53	1.76	2.3	1.92	2.13	1.28	0.59	0.57	0.75	1.68	2.87	2.47	20.85
YAKIMA, WA	1.14	0.78	0.62	0.55	0.58	0.62	0.22	0.26	0.36	0.54	1.05	1.53	8.25
BECKLEY, WV	2.81	2.76	3.57	3.36	4.66	4	5.03	3.47	3.01	2.57	2.95	3	41.19
CHARLESTON, WV	3	3.19	3.91	3.24	4.8	4.29	4.94	3.74	3.25	2.67	3.73	3.27	44.03
ELKINS, WV	3.43	3.20	3.92	3.53	4.77	4.61	4.84	4.26	3.83	2.86	3.42	3.44	46.11
HUNTINGTON, WV	2.97	3.07	3.9	3.44	4.7	3.88	4.55	3.74	2.78	2.81	3.44	3.31	42.59
GREEN BAY, WI	1.13	1.11	1.85	2.63	2.93	3.88	3.5	3.37	3.04	2.44	2.13	1.51	29.52
LA CROSSE, WI	1.12	1.05	2.04	3.34	3.52	4.34	4.26	4.29	3.56	2.17	2.01	1.36	33.06
MADISON, WI	1.23	1.45	2.2	3.4	3.55	4.54	4.18	4.27	3.13	2.4	2.39	1.74	34.48
MILWAUKEE, WI	1.76	1.65	2.27	3.56	3.4	3.9	3.67	3.97	3.18	2.65	2.71	2.04	34.76
CASPER, WY	0.51	0.57	0.82	1.29	2.02	1.61	1.41	0.85	1.08	1.11	0.76	0.49	12.52
CHEYENNE, WY	0.33	0.47	1.05	1.78	2.34	2.34	2.19	1.95	1.48	0.93	0.59	0.49	15.94

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Average Rainfall Normals, 1981 – 2010 (inches)													
	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
LANDER, WY	1.11	0.66	1.92	2.07	1.76	1.19	0.86	0.87	1.16	1.42	1.17	1.36	15.55
SHERIDAN, WY	0.56	0.54	0.98	1.6	2.35	2.12	1.18	0.72	1.43	1.41	0.71	0.56	14.16
GUAM, PC	4.96	4.53	2.77	3.58	4.3	7.09	12.14	17.15	14.17	11.8	9.17	5.98	97.64
JOHNSTON ISLAND, PC	1.91	1.32	2.14	1.84	1.01	0.9	1.33	2.03	2.71	3.66	4.88	2.74	26.47
KOROR, PC	11.09	9.54	8.27	8.19	12.52	18.01	18.12	13.92	12.09	12.06	11.9	11.93	147.64
KWAJALEIN MARSHALL IS, P	4.01	3.3	3.56	6.21	6.61	7.86	9.85	10.4	10.89	11.83	11.07	8.13	93.72
MAJURO MARSHALL IS, PC	8.28	7.62	7.55	9.63	9.86	10.93	11.93	11.42	12.14	13.27	13.23	11.56	127.42
PAGO PAGO AMER SAMOA, PC	14.48	12.66	11.66	11.02	10.62	5.86	6.47	6.3	7.63	10.11	11.3	14.52	122.63
POHNPEI CAROLINE IS, PC	13.21	10.02	14.13	17.75	18.35	15.77	16.09	14.82	14.9	15.27	15	15.91	181.22
CHUUK E CAROLINE IS, PC	10.14	7.26	8.81	12.22	11.73	12.21	12.39	13.48	12.85	11.4	11.03	11.02	134.54
WAKE ISLAND, PC	1.4	1.72	2.25	2.2	1.76	1.92	4.18	5.44	4.61	4.39	2.69	1.9	34.46
YAP W CAROLINE IS, PC	7.3	5.99	5.34	5.72	8.5	13.2	15.04	15.46	13.76	12.25	9.09	9.28	120.93
SAN JUAN, PR	3.76	2.39	1.95	4.68	5.9	4.41	5.07	5.46	5.77	5.59	6.35	5.02	56.35
Source: NOAA National Weather Service													

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Microbial Treatment Through a Rainwater Harvesting System Designed to the ARCSA/ASPE/ANSI Standard 63

December 2024

Introduction:

ARCSA/ASPE/ANSI Standard 63 is a Plumbing Engineering and Design Standard for Rainwater Catchment Systems that supports a four-step process to encourage natural biofilms as part of the water filtration and treatment. This four-step process is not found in any other national or global standard and sets Standard 63 above all other processes to create the cleanest water possible in a rainwater harvesting system. This document sets out to estimate the effectiveness of ARCSA/ASPE/ANSI Standard 63 in reducing microbial concentrations in supplied rainwater by calculating log reduction values for the system components. The estimates are based on a literature survey of peer reviewed articles to evaluate the potential log reduction values associated with the four-step process in supplied rainwater.

The four steps include prefiltration, a smoothing inlet, a floating filter intake, and a skimming overflow. The prefiltration step removes large particulate matter, which carries and feeds bacteria. It also oxygenates the water in the tank, greatly reducing the number of harmful bacteria in the tank. The smoothing or calming inlet is designed to direct the incoming water upwards to prevent disturbance of the biofilm that has settled to the bottom of the tank. The biofilm at the bottom, and some found on the walls of the tank, work to eliminate bad bacteria, therefore creating a healthier water environment. The floating filter draws water out of the tank below the surface of the water to avoid any floating particulate. This ensures water is drawn where the cleanest water in the tank is found. The skimming overflow removes the floating particulate off the surface of the water while also providing an excess water overflow. This overflow should also eliminate vectors and vermin as well as backflow from any storm drains.

There are additional cleansing processes that occur in the tank with biofilms, and there are multiple studies on these processes. However, there are no definitive results from these studies, and additional research is needed to determine how these four steps combined work to affect biofilms in stored rainwater. This study only analyzed the four-step process found in Standard 63 as it relates to log reductions and water quality in supplied rainwater. The post filtration processes typically include proven filters and disinfection

treatment trains and equipment that have been assigned proven log reduction levels. There has never been a log reduction assigned to the Standard 63 four-step process, though this project argues that the four-step process does provide log reduction values and should be recognized as a valid treatment method for rainwater catchment systems.

There is additional research needed that analyzes rainwater runoff from various roof surfaces and the four-step process in Standard 63. Those aspects still need assigned a level of participation in creating high water quality, but those aspects will vary greatly by rainfall quantity, rainfall timing, system location, and catchment surface. Part of the process is the time between rainfall events when everything dies in the tank and settles to the bottom of the tank. That is when the cleanest water is found in a tank. There are two zones in a tank - the top aerobic, where we pump water from and the bottom 6-inch anaerobic zone, that we try not to disturb when new water is added to a tank. This paper evaluates the literature available for the elements in the four-step process while knowing there are many other factors that contribute to the water quality in a Standard 63 rainwater catchment system.

It is ARCSA International's primary goal to assign a minimum of a two-log reduction to the ARCSA/ASPE/ANSI Standard 63 rainwater harvesting system design involving the four-step process for bacterial reduction based on the following literature review and the additional knowledge that natural processes found in a well-designed rainwater tank only add to the high-water quality. Currently, the post tank filtration and purification steps required by Standard 63 will eliminate viruses and protozoa. However, log reduction tables typically show zero log reduction targets for viruses and a 1-1.5 log reduction target for protozoa (per DALY and California respectively) contaminants which will additionally be eliminated in the post tank filtration and purification.

Microbial treatment from pre-tank and in-tank processes required by Standard 63

Purpose: The goal of this project was to estimate the effectiveness of ARCSA/ASPE/ANSI Standard 63 in reducing microbial concentrations in supplied rainwater relative to direct roof runoff by calculating log reduction values for the required system components. This project focused on pre-tank and in-tank components of rainwater harvesting system design. The components include pre-tank filtration, optional diversion of the first flush of rainwater, a calming inlet and floating filter, which encourage settling and biofilm development in the tank, and a protected overflow device.

Approach: The estimates in this study are based on a literature survey. Journal articles were collected using Randolph College's OneSearch from EBSCO. The search terms and the number of articles found with these search terms are included in Table 1. In many cases, papers were found using multiple search terms, making the total number of papers reviewed for this project lower than the sum of the number of papers found with the search terms.

Search terms	# of papers found
rainwater and harvest* and filt*	145
rainwater and harvest* and debris exclu*	0
rainwater and harvest* and biofilm	19
rainwater and harvest* and settling	1
rainwater and harvest* and first flush	46

Table 1: Search terms used to find journal articles for this analysis and the number of papers found for each set of terms.

To calculate a log reduction value, two estimates of microbial concentrations were needed – an estimate of the concentration without the system component and an estimate of the concentration with treatment by the system component. For standard post-tank water treatment components, such as ultraviolet lights, these two measurements are typically taken before and after the treatment component. The log reduction is then calculated as

$$\text{Log reduction} = \log_{10}\left(\frac{Concentration\ before\ treatment}{Concentration\ after\ treatment}\right)$$

Based on this, for inclusion in this analysis, a research paper needed to provide paired measurements of concentration with and without the system component. These paired measurements could either be measurements at two points within the same system (e.g. before the storage tank and after the storage tank) or measurements from paired systems, one with the component and one without (e.g. measurements of bacterial concentration in the storage tank of a rainwater harvesting system with a pre-tank filter and measurement of bacterial concentration in the storage tank of an adjacent rainwater harvesting system without a pre-tank filter). In addition, only papers from peer-reviewed publications were included and papers studying post-tank treatment only were excluded. Conference papers were not included. Out of all of the papers reviewed for this project, 15 papers included data that could be used to calculate log reduction values, 185 papers were not suitable for calculating log reduction values.

Findings: All of the log reduction values calculated are included in Appendix A. A list of the excluded papers, including a brief note of the reason for exclusion is included in Appendix B.

A summary of the findings, showing mean log reductions by component is shown in Table 2.

Rainwater harvesting system component	*E. coli*	Fecal coliforms	Total coliforms	Other bacteria*
Pre-tank filter and first flush	0.1	0.1	0.1	
Pre-tank filter			0.5	
First flush**	1.2	0.4	0.5	1.1
In-tank processes***	1.1	0.2	0.3	0.8
Overflow**	1.7		1.0	1.5
Full system - no post-tank treatment	0.5	0.8	1.0	

Table 2. Mean log reduction values calculated for different pre-tank and in-tank rainwater harvesting system components.
*This category includes data on heterotrophic plate count, viable count at 30℃, Pseudomonas, Enterococcus and thermotolerant coliforms. These types of bacteria were studied less frequently and are pooled for ease of analysis. These bacterial groups would not necessarily be expected to respond similarly to treatment. However, because the treatment studied here is largely mechanical, the treatment efficacy on these different groups of different parts of the rainwater harvesting system are likely small. All of the individual data points are available in Appendix A.
** This value is likely an overestimate of the impact of the first flush and overflow. See details below.
*** In-tank processes includes the biofilm, floating filter, and settling

<u>Pre-tank filtration and first flush</u> - Pre-tank filtration, which is required in Standard 63, has received very little research attention. Two studies (Costa *et al,* 2021, Taffere *et al,* 2017) examined novel pre-tank filters, designed specifically for the study. No log reduction

value could be calculated from the Costa *et al* (2021) study because the initial bacterial concentrations were below the limit of detection. A single study (Amin *et al*, 2013) examined the impact of a combined first flush and pre-tank filter system and found modest log reductions. This leaves the impact of pre-tank filtration on the quality of harvested rainwater largely unstudied.
Diversion of the first flush is an optional feature of rainwater harvesting systems designed in accordance with Standard 63. However, it is included here because of the research attention given to the first flush.The estimates of log reductions due to first flush diversion (based on Gikas and Tsihrintzis, 2012; Gikas and Tsihrintzis, 2017; Lee *et al,* 2011; Mendez *et al,* 2011; Morgoda *et al,* 2022; Sambas *et al,* 2019; van der Sterren *et al,* 2023) are calculated by comparing the water quality in the first flush water to stored water in the tank. This is certainly an overestimation because the first flush water would be diluted in the tank. These values are included in the table because of the emphasis the first flush has received in the research literature, but should not be considered a true estimate of the impact of first flush diversion.

<u>In-tank processes</u> - In-tank processes can be measured by comparing the water quality at an elevated uptake point to water quality lower in the tank, mimicking the ability of a floating filter to take cleaner water as settling occurs or by measuring the water entering the storage tank and as it is pumped from the storage tank. Log reduction values for these processes range from 0.2 - 1.1 for the different bacterial components studied, with a median of 0.8 (based on Amin *et al,* 2013; Andriamanantena *et al,* 2021; Kim and Han, 2014; Kim and Han, 2015; Tran *et al,* 2021; var der Merwe, 2013).

<u>Overflow</u> - A single study (van der Sterren *et al*, 2013) compared the concentration of microbial contaminants in an overflow tank with the concentration in the main rainwater harvesting storage tank. Similar to the challenges of estimating the impacts of the first flush, this compares the concentration of a contaminant in a small volume removed from a much larger tank to the concentration in the larger tank. If all of the overflow water (or the first flush water) was added to the larger storage tank, the impact on the concentration of the microbial contaminant in the storage tank would not be as large as implied by a log reduction value calculated just comparing these concentrations because of dilution.

<u>Full system</u> - A single study also examined the water quality benefits of a full system, including first flush diversion, pre-tank filtering and in-tank processes, without including post-tank treatment (Amin *et al*, 2013). For the bacterial components measured, the log reduction ranged from 0.5-1.2, depending on the bacterial component considered. Other studies (Barriga *et al*, 2024; Khalid and Alodah, 2023) provide information on the log reduction of a full rainwater harvesting system, including post-tank treatment, but these studies were not included in the table

Limitations: Much of the research literature on rainwater harvesting still focuses on identification of microbial contamination in rainwater harvesting tanks, with little emphasis on the impacts of treatment. Typically, when treatment is considered, researchers study post-tank treatment or first-flush diversion. The limitations of many of these studies on first-flush diversion are discussed below.

Virtually all of the research on viruses in rainwater harvesting systems uses molecular techniques to identify the viruses. These techniques identify the genetic material of the virus, and therefore will detect both active and inactive viruses. Because of this, only physical removal of viruses, through settling, diversion or filtration can be measured. In addition, few of the studies quantify the viral load.

A further limitation is that viruses and protozoa in rainwater harvesting systems are relatively understudied compared to bacteria, particularly bacterial indicator organisms such as total coliforms. This literature survey did not discover any studies that measure either of these contaminants at multiple points in a single rainwater harvesting system, except those that measure post-tank treatment.

The literature surveyed also did not include any studies that feature a controlled comparison of a rainwater harvesting system (or multiple systems) designed with components included in Standard 63 and a system (or systems) without those components.

Finally, many of the water quality benefits of appropriate rainwater harvesting design are based on in-tank processes that reduce the microbial contamination through settling and death/inactivation. For example, preventing organic debris from entering the storage tank reduces the nutrient load available for bacteria. These processes contribute to overall improvement of the water quality in rainwater harvesting tanks; however, without paired studies of rainwater harvesting systems with and without appropriate design, the impact of these features is difficult to determine.

Conclusion: In summary, the research literature does not provide sufficient evidence to ascribe a log reduction value for appropriately designed rainwater harvesting systems for viruses or protozoa. However, the research on rainwater harvesting systems demonstrates that the pre-tank and in-tank components of a rainwater harvesting system effectively reduce bacterial concentrations and a log reduction value between 1 and 2 is appropriate for these systems.

References:

Amin, M. T., Kim, T. I., Amin, M. N., & Han, M. Y. (2013). Effects of Catchment, First-Flush, Storage Conditions, and Time on Microbial Quality in Rainwater Harvesting Systems. Water Environment Research, 85(12), 2317-2329

Andriamanantena R., V., Kim, M., & Han, M. (2021). Effect of Visible Light on Surface-Attached and Suspended Heterotrophic Bacteria in a Typical Household Rainwater Harvesting Tank. Sustainability, 13(10), 5410-. https://doi.org/10.3390/su13105410

Barriga, F., Gómez, G., Diez, M. C., Fernandez, L., & Vidal, G. (2024). Influence of Catchment Surface Material on Quality of Harvested Rainwater. Sustainability, 16(15), 6586-. https://doi.org/10.3390/su16156586

Costa, P. C. L. da, Azevedo, A. R. G. de, Silva, F. C. da, Cecchin, D., & Carmo, D. de F. do. (2021). Rainwater treatment using an acrylic blanket as a filtering media. Journal of Cleaner Production, 303, 126964-. https://doi.org/10.1016/j.jclepro.2021.126964

Gikas, G. D., & Tsihrintzis, V. A. (2012). Assessment of water quality of first-flush roof runoff and harvested rainwater. Journal of Hydrology, 466, 115-126.

Gikas, G. D., & Tsihrintzis, V. A. (2017). Effect of first-flush device, roofing material, and antecedent dry days on water quality of harvested rainwater. Environmental Science and Pollution Research, 24, 21997-22006.

Khalid, B., & Alodah, A. (2023). Multivariate Analysis of Harvested Rainwater Quality Utilizing Sustainable Solar-Energy-Driven Water Treatment. Sustainability, 15(19), 14568-. https://doi.org/10.3390/su151914568

Kim, M., & Han, M. (2014). Characteristics of biofilm development in an operating rainwater storage tank. Environmental earth sciences, 72, 1633-1642.

Lee, J. Y., Kim, H. J., & Han, M. Y. (2011). Quality assessment of rooftop runoff and harvested rainwater from a building catchment. Water Science and Technology, 63(11), 2725-2731.

Mendez, C. B., Klenzendorf, J. B., Afshar, B. R., Simmons, M. T., Barrett, M. E., Kinney, K. A., & Kirisits, M. J. (2011). The effect of roofing material on the quality of harvested rainwater. Water Research (Oxford), 45(5), 2049–2059. https://doi.org/10.1016/j.watres.2010.12.015

Morgado, M. E., Hudson, C. L., Chattopadhyay, S., Ta, K., East, C., Purser, N., Allard, S., Ferrier, M. D., Sapkota, A. R., Sharma, M., & Goldstein, R. R. (2022). The effect of a first flush rainwater harvesting and subsurface irrigation system on E. coli and pathogen concentrations in irrigation water, soil, and produce. The Science of the Total Environment, 843, 156976–156976. https://doi.org/10.1016/j.scitotenv.2022.156976

Sambas, N. F. B., Baloo, L., & Mustaffa, A. P. Z. (2019). Rainwater harvesting with subsequent first flush: Water quality performance for non-potable purpose. International Journal of Recent Technology and Engineering, 8(2 Spec), 76-79.

Tran, S. H., Dang, H. T. T., Dao, D. A., Nguyen, V.-A., Nguyen, L. T., & Han, M. (2021). On-site rainwater harvesting and treatment for drinking water supply: assessment of cost and technical issues. Environmental Science and Pollution Research International, 28(10), 11928–11941. https://doi.org/10.1007/s11356-020-07977-0

van der Merwe, V., Duvenage, S., & Korsten, L. (2013). Comparison of biofilm formation and water quality when water from different sources was stored in large commercial water storage tanks. Journal of water and health, 11(1), 30–40. https://doi.org/10.2166/wh.2012.014

van der Sterren, M., Rahman, A., & Dennis, G. R. (2013). Quality and Quantity Monitoring of Five Rainwater Tanks in Western

Sydney, Australia. Journal of Environmental Engineering (New York, N.Y.), 139(3), 332–340. https://doi.org/10.1061/(ASCE)EE.1943-7870.0000614

Appendix A: Calculated log reduction values for rainwater harvesting system components

Rainwater harvesting system component	Water quality constituent	Log reduction	Reference	Notes
First flush	*E. coli*	0.4	Lee, J. Y., Kim, H. J., & Han, M. Y. (2011). Quality assessment of rooftop runoff and harvested rainwater from a building catchment. Water Science and Technology, 63(11), 2725-2731.	This is likely an overestimate - this compares the concentration at 5 minutes after the start of the rain (identified as the highest turbidity) with stored water quality -- the stored water quality was typically worse than the water quality after 100 min of runoff (collected directly from the roof). Data was estimated from figure 3.
First flush	*E. coli*	0.6	Morgado, M. E., Hudson, C. L., Chattopadhyay, S., Ta, K., East, C., Purser, N., Allard, S., Ferrier, M. D., Sapkota, A. R., Sharma, M., & Goldstein, R. R. (2022). The effect of a first flush rainwater harvesting and subsurface irrigation system on E. coli and pathogen concentrations in irrigation water, soil, and produce. The Science of the Total Environment, 843, 156976–156976. https://doi.org/10.1016/j.scitotenv.2022.156976	This value represents a comparison of first flush water quality with "irrigation water" quality at site RC. Site HC was not included because the irrigation water was sampled from observation wells after influence from soil
First flush	*E. coli*	2.5	van der Sterren, M., Rahman, A., & Dennis, G. R. (2013). Quality and Quantity Monitoring of Five Rainwater Tanks in Western Sydney, Australia. Journal of Environmental Engineering (New York, N.Y.), 139(3), 332–340. https://doi.org/10.1061/(ASCE)EE.1943-7870.0000614	This value is likely an overestimation and compares water quality of the first flush with the water quality stored in the tank.

First flush	*Enterococcus*	1.1	van der Sterren, M., Rahman, A., & Dennis, G. R. (2013). Quality and Quantity Monitoring of Five Rainwater Tanks in Western Sydney, Australia. Journal of Environmental Engineering (New York, N.Y.), 139(3), 332–340. https://doi.org/10.1061/(ASCE)EE.1943-7870.0000614	This value is likely an overestimation and compares water quality of the first flush with the water quality stored in the tank.
First flush	Fecal coliforms	0.4	Mendez, C. B., Klenzendorf, J. B., Afshar, B. R., Simmons, M. T., Barrett, M. E., Kinney, K. A., & Kirisits, M. J. (2011). The effect of roofing material on the quality of harvested rainwater. Water Research (Oxford), 45(5), 2049–2059. https://doi.org/10.1016/j.watres.2010.12.015	This value is estimated based on the data in figure 4. It represents the difference in concentration between the first flush and the stored water.
First flush	HPC	0.7	Lee, J. Y., Kim, H. J., & Han, M. Y. (2011). Quality assessment of rooftop runoff and harvested rainwater from a building catchment. Water Science and Technology, 63(11), 2725-2731.	This is likely an overestimate - this compares the concentration at 5 minutes after the start of the rain (identified as the highest turbidity) with stored water quality -- the stored water quality was typically worse than the water quality after 100 min of runoff (collected directly from the roof). Data was estimated from figure 3.
First flush	Thermotolerant coliforms	1.5	van der Sterren, M., Rahman, A., & Dennis, G. R. (2013). Quality and Quantity Monitoring of Five Rainwater Tanks in Western Sydney, Australia. Journal of Environmental Engineering (New York, N.Y.), 139(3), 332–340. https://doi.org/10.1061/(ASCE)EE.1943-7870.0000614	This value is likely an overestimation and compares water quality of the first flush with the water quality stored in the tank.

First flush	Total coliforms	0.0	Gikas, G. D., & Tsihrintzis, V. A. (2012). Assessment of water quality of first-flush roof runoff and harvested rainwater. Journal of Hydrology, 466, 115-126.	Six total systems represented in the study -- only four had paired median values of water in the first flush and water in the tank.
First flush	Total coliforms	-0.2	Gikas, G. D., & Tsihrintzis, V. A. (2017). Effect of first-flush device, roofing material, and antecedent dry days on water quality of harvested rainwater. Environmental Science and Pollution Research, 24, 21997-22006.	Compared water quality in the first flush diverter to water quality in two tanks, actually found more microbial contamination in the tanks
First flush	Total coliforms	0.7	Lee, J. Y., Kim, H. J., & Han, M. Y. (2011). Quality assessment of rooftop runoff and harvested rainwater from a building catchment. Water Science and Technology, 63(11), 2725-2731.	This is likely an overestimate - this compares the concentration at 5 minutes after the start of the rain (identified as the highest turbidity) with stored water quality -- the stored water quality was typically worse than the water quality after 100 min of runoff (collected directly from the roof). Data was estimated from figure 3.
First flush	Total coliforms	0.4	Mendez, C. B., Klenzendorf, J. B., Afshar, B. R., Simmons, M. T., Barrett, M. E., Kinney, K. A., & Kirisits, M. J. (2011). The effect of roofing material on the quality of harvested rainwater. Water Research (Oxford), 45(5), 2049–2059. https://doi.org/10.1016/j.watres.2010.12.015	This value is estimated based on the data in figure 4. It represents the difference in concentration between the first flush and the stored water.
First flush	Total coliforms	0.2	Sambas, N. F. B., Baloo, L., & Mustaffa, A. P. Z. (2019). Rainwater harvesting with subsequent first flush: Water quality performance for non-potable purpose. International Journal of Recent Technology and Engineering, 8(2 Spec), 76-79.	This is the comparison of the first first flush tank of 5 liters to the last first flush tank of 5 liters (there were 5 in total).

First flush	Total coliforms	1.9	van der Sterren, M., Rahman, A., & Dennis, G. R. (2013). Quality and Quantity Monitoring of Five Rainwater Tanks in Western Sydney, Australia. Journal of Environmental Engineering (New York, N.Y.), 139(3), 332–340. https://doi.org/10.1061/(ASCE)EE.1943-7870.0000614	This value is likely an overestimation and compares water quality of the first flush with the water quality stored in the tank.
Floating filter	*E. coli*	0.2	Amin, M. T., Kim, T. I., Amin, M. N., & Han, M. Y. (2013). Effects of Catchment, First-Flush, Storage Conditions, and Time on Microbial Quality in Rainwater Harvesting Systems. Water Environment Research, 85(12), 2317-2329.	These values are calculated from concentrations estimated from Fig. 3a and are values for system 1. The value is calculated as log(10)(average surface and midway concentration/average point of supply concentration) -- these numbers more accurately represent the difference between the surface and a lower point than the elevation of a traditional floating filter. The point of supply was 0.5m above the bottom of the tank, which was 2 m tall.
Floating filter	*E. coli*	0.4	Amin, M. T., Kim, T. I., Amin, M. N., & Han, M. Y. (2013). Effects of Catchment, First-Flush, Storage Conditions, and Time on Microbial Quality in Rainwater Harvesting Systems. Water Environment Research, 85(12), 2317-2329.	These values are calculated from concentrations estimated from Fig. 5a and are values for system 2. The value is calculated as log(10)(average all points except the point of supply/average point of supply concentration) -- The point of supply was 1.35 m above the bottom of the tank, which was 4.7 m tall.

In-tank settling (see note)	*E. coli*	2.8	Tran, S. H., Dang, H. T. T., Dao, D. A., Nguyen, V.-A., Nguyen, L. T., & Han, M. (2021). On-site rainwater harvesting and treatment for drinking water supply: assessment of cost and technical issues. Environmental Science and Pollution Research International, 28(10), 11928–11941. https://doi.org/10.1007/s11356-020-07977-0	This represents the numerical mean of the log reductions calculated for the single system for which data is reported in 2018 and 2019. The water was sampled in the sedimentation tank and then just before filtration. The first flush was diverted before the sedimentation tank. Zero values (all values after filtration) were replaced with 1 CFU/100 ml as a conservative estimate.
Floating filter	Fecal coliforms	0.3	Amin, M. T., Kim, T. I., Amin, M. N., & Han, M. Y. (2013). Effects of Catchment, First-Flush, Storage Conditions, and Time on Microbial Quality in Rainwater Harvesting Systems. Water Environment Research, 85(12), 2317-2329.	These values are calculated from concentrations estimated from Fig. 3a and are values for system 1. The value is calculated as log(10)(average surface and midway concentration/average point of supply concentration) -- these numbers more accurately represent the difference between the surface and a lower point than the elevation of a traditional floating filter. The point of supply was 0.5m above the bottom of the tank, which was 2 m tall.
Floating filter	Fecal coliforms	0.1	Amin, M. T., Kim, T. I., Amin, M. N., & Han, M. Y. (2013). Effects of Catchment, First-Flush, Storage Conditions, and Time on Microbial Quality in Rainwater Harvesting Systems. Water Environment Research, 85(12), 2317-2329.	These values are calculated from concentrations estimated from Fig. 5a and are values for system 2. The value is calculated as log(10)(average all points except the point of supply/average point of supply concentration) -- The point of supply was 1.35 m above the bottom of the tank, which was 4.7 m tall.

Floating filter	HPC	0.7	Amin, M. T., Kim, T. I., Amin, M. N., & Han, M. Y. (2013). Effects of Catchment, First-Flush, Storage Conditions, and Time on Microbial Quality in Rainwater Harvesting Systems. Water Environment Research, 85(12), 2317-2329.	These values are calculated from concentrations estimated from Fig. 3a and are values for system 1. The value is calculated as log(10)(average surface and midway concentration/average point of supply concentration) -- these numbers more accurately represent the difference between the surface and a lower point than the elevation of a traditional floating filter. The point of supply was 0.5m above the bottom of the tank, which was 2 m tall.
Floating filter	HPC	0.6	Amin, M. T., Kim, T. I., Amin, M. N., & Han, M. Y. (2013). Effects of Catchment, First-Flush, Storage Conditions, and Time on Microbial Quality in Rainwater Harvesting Systems. Water Environment Research, 85(12), 2317-2329.	These values are calculated from concentrations estimated from Fig. 5a and are values for system 2. The value is calculated as log(10)(average all points except the point of supply/average point of supply concentration) -- The point of supply was 1.35 m above the bottom of the tank, which was 4.7 m tall.
Biofilm and settling	HPC	0.2	van der Merwe, V., Duvenage, S., & Korsten, L. (2013). Comparison of biofilm formation and water quality when water from different sources was stored in large commercial water storage tanks. Journal of water and health, 11(1), 30–40. https://doi.org/10.2166/wh.2012.014	Reduction over 5 days

In-tank settling (see note)	HPC	1.0	Andriamanantena R., V., Kim, M., & Han, M. (2021). Effect of Visible Light on Surface-Attached and Suspended Heterotrophic Bacteria in a Typical Household Rainwater Harvesting Tank. Sustainability, 13(10), 5410-. https://doi.org/10.3390/su13105410	The heterotrophic plate count in the tank initially increased to approximately 3.5 (Fig. 5b), likely due to mixing of bacteria and available carbon sources when water was transferred from the rainwater harvesting system into this experimental tank. This value is based on the difference between the peak suspended heterotrophic plate count and the value one week later. These samples are from the tank stored without sunlight exposure to mimic appropriate design as required by Standard 63.
Biofilm and settling	*Pseudomonas*	2.0	Kim, M., & Han, M. (2015). Role of biofilms in improving microbial quality in rainwater tanks. Desalination and Water Treatment, 53(10), 2579-2584.	Based on 4-5 day reduction in concentration of two rainwater harvesting systems
In-tank settling (see note)	*Pseudomonas*	0.5	Tran, S. H., Dang, H. T. T., Dao, D. A., Nguyen, V.-A., Nguyen, L. T., & Han, M. (2021). On-site rainwater harvesting and treatment for drinking water supply: assessment of cost and technical issues. Environmental Science and Pollution Research International, 28(10), 11928–11941. https://doi.org/10.1007/s11356-020-07977-0	This represents the numerical mean of the log reductions calculated for the two systems for which data is reported in 2018 and 2019. The water was sampled in the sedimentation tank and then just before filtration. The first flush was diverted before the sedimentation tank. Zero values after filtration) were replaced with 1 CFU/100 ml as a conservative estimate. Data was not included for which the initial value was zero.

In-tank settling and biofilms (see note)	Viable bacteria at 30 degrees C	0.5	Kim, M., & Han, M. (2014). Characteristics of biofilm development in an operating rainwater storage tank. Environmental earth sciences, 72, 1633-1642.	This is between the inlet and outlet of a storage tank with baffles/walls set up to encourage settling. Biofilm growth was also monitored but impact on water quality was not directly measured --- improvement in water quality was attributed to the biofilm.
Floating filter	Total coliforms	0.3	Amin, M. T., Kim, T. I., Amin, M. N., & Han, M. Y. (2013). Effects of Catchment, First-Flush, Storage Conditions, and Time on Microbial Quality in Rainwater Harvesting Systems. Water Environment Research, 85(12), 2317-2329.	These values are calculated from concentrations estimated from Fig. 3a and are values for system 1. The value is calculated as log(10)(average surface and midway concentration/average point of supply concentration) -- these numbers more accurately represent the difference between the surface and a lower point than the elevation of a traditional floating filter. The point of supply was 0.5m above the bottom of the tank, which was 2 m tall.
Floating filter	Total coliforms	0.2	Amin, M. T., Kim, T. I., Amin, M. N., & Han, M. Y. (2013). Effects of Catchment, First-Flush, Storage Conditions, and Time on Microbial Quality in Rainwater Harvesting Systems. Water Environment Research, 85(12), 2317-2329.	These values are calculated from concentrations estimated from Fig. 5a and are values for system 2. The value is calculated as log(10)(average all points except the point of supply/average point of supply concentration) -- The point of supply was 1.35 m above the bottom of the tank, which was 4.7 m tall.
In-tank settling (see note)	Total coliforms	0.4	Tran, S. H., Dang, H. T. T., Dao, D. A., Nguyen, V.-A., Nguyen, L. T., & Han, M. (2021). On-site rainwater harvesting and treatment for drinking water supply: assessment of cost and technical issues. Environmental Science and Pollution	This represents the numerical mean of the log reductions calculated for the three sampled systems in 2018 and 2019. The water was sampled in the sedimentation tank and then just before filtration. The

			Research International, 28(10), 11928–11941. https://doi.org/10.1007/s11356-020-07977-0	first flush was diverted before the sedimentation tank.
Full system - including aeration tank, filtration (adsorption and sediment filtration), UV disinfection, first flush diversion and floating filter	Total coliforms	3.5	Khalid, B., & Alodah, A. (2023). Multivariate Analysis of Harvested Rainwater Quality Utilizing Sustainable Solar-Energy-Driven Water Treatment. Sustainability, 15(19), 14568-. https://doi.org/10.3390/su151914568	This value is calculated from the mean concentration of unfiltered rainwater and rainwater treated by the system - it is unclear how the untreated samples were collected
Full system - including aeration tank, filtration (adsorption and sediment filtration), UV disinfection, first flush diversion and floating filter	*E. coli*	3.0	Khalid, B., & Alodah, A. (2023). Multivariate Analysis of Harvested Rainwater Quality Utilizing Sustainable Solar-Energy-Driven Water Treatment. Sustainability, 15(19), 14568-. https://doi.org/10.3390/su151914568	This value is calculated from the mean concentration of unfiltered rainwater and rainwater treated by the system - it is unclear how the untreated samples were collected
Full system - no post-tank treatment	*E. coli*	0.5	Amin, M. T., Kim, T. I., Amin, M. N., & Han, M. Y. (2013). Effects of Catchment, First-Flush, Storage Conditions, and Time on Microbial Quality in Rainwater Harvesting Systems. Water Environment Research, 85(12), 2317-2329.	These values are calculated from percent reductions given in the text in the first paragraph on page 2323. NOTE: The text specifies that the reductions were "almost" this value.
Full system - no post-tank treatment	Fecal coliforms	0.8	Amin, M. T., Kim, T. I., Amin, M. N., & Han, M. Y. (2013). Effects of Catchment, First-Flush, Storage Conditions, and Time on Microbial Quality in Rainwater Harvesting Systems. Water Environment Research, 85(12), 2317-2329.	These values are calculated from percent reductions given in the text in the first paragraph on page 2323. NOTE: The text specifies that the reductions were "almost" this value.
Full system - no post-tank treatment	Total coliforms	1.0	Amin, M. T., Kim, T. I., Amin, M. N., & Han, M. Y. (2013). Effects of Catchment, First-Flush, Storage Conditions, and Time on Microbial Quality in	These values are calculated from percent reductions given in the text in the first paragraph on page 2323. NOTE: The text

			Rainwater Harvesting Systems. Water Environment Research, 85(12), 2317-2329.	specifies that the reductions were "almost" this value.
Full system - no post-tank treatment	HPC	1.2	Amin, M. T., Kim, T. I., Amin, M. N., & Han, M. Y. (2013). Effects of Catchment, First-Flush, Storage Conditions, and Time on Microbial Quality in Rainwater Harvesting Systems. Water Environment Research, 85(12), 2317-2329.	These values are calculated from percent reductions given in the text in the first paragraph on page 2323. NOTE: The text specifies that the reductions were "almost" this value.
Full system, including chlorination and post-tank filtration	Fecal coliforms	0.7	Barriga, F., Gómez, G., Diez, M. C., Fernandez, L., & Vidal, G. (2024). Influence of Catchment Surface Material on Quality of Harvested Rainwater. Sustainability, 16(15), 6586-. https://doi.org/10.3390/su16156586	This is only for one site because it was the only site with an initial number for the coliform data in the untreated rainwater (2.7, all others were <1 MPN/100 ml). The value after treatment was <1, which was taken to be 0.5. The whole system is described as "The rainwater was captured by the different roof surfaces and conveyed through gutters to a stainless-steel mesh filter to retain leaves and larger solids. Then, the first millimeters of rain were conveyed to the first flush diverter to prevent particles, sediment, coloring, organic matter, and even pathogens that had accumulated on the roof, as well as pesticides and organic compounds entrained by the rain from the air, from reaching the water storage tank [14,16]. Once the rainwater reached the storage tank, it was disinfected by dosing with calcium hypochlorite (65% strength) in accordance with local regulations and the

				intended use of the harvested water. Finally, the water was extracted with a 0.5-HP pump to then pass through two filters with different pore sizes (130 µm and 5 µm) and harvested at the outlet tap for its end use."
Full system, including chlorination and post-tank filtration	Total coliforms		Barriga, F., Gómez, G., Diez, M. C., Fernandez, L., & Vidal, G. (2024). Influence of Catchment Surface Material on Quality of Harvested Rainwater. Sustainability, 16(15), 6586-. https://doi.org/10.3390/su16156586	Unable to calculate, because of low initial values (<1 MPN/100 ml)
Full system, including chlorination and post-tank filtration	*E. coli*		Barriga, F., Gómez, G., Diez, M. C., Fernandez, L., & Vidal, G. (2024). Influence of Catchment Surface Material on Quality of Harvested Rainwater. Sustainability, 16(15), 6586-. https://doi.org/10.3390/su16156586	Unable to calculate, because of low initial values (<1 MPN/100 ml)
Overflow	*E. coli*	1.7	van der Sterren, M., Rahman, A., & Dennis, G. R. (2013). Quality and Quantity Monitoring of Five Rainwater Tanks in Western Sydney, Australia. Journal of Environmental Engineering (New	This value compares concentrations measured in an overflow collection device to the water quality measured in the tank. The paper included limited detail on the

			York, N.Y.), 139(3), 332–340. https://doi.org/10.1061/(ASCE)EE.1943-7870.0000614	configuration of the overflow.
Overflow	Total coliforms	1.0	van der Sterren, M., Rahman, A., & Dennis, G. R. (2013). Quality and Quantity Monitoring of Five Rainwater Tanks in Western Sydney, Australia. Journal of Environmental Engineering (New York, N.Y.), 139(3), 332–340. https://doi.org/10.1061/(ASCE)EE.1943-7870.0000614	This value compares concentrations measured in an overflow collection device to the water quality measured in the tank. The paper included limited detail on the configuration of the overflow.
Overflow	*Enterococcus*	2.0	van der Sterren, M., Rahman, A., & Dennis, G. R. (2013). Quality and Quantity Monitoring of Five Rainwater Tanks in Western Sydney, Australia. Journal of Environmental Engineering (New York, N.Y.), 139(3), 332–340. https://doi.org/10.1061/(ASCE)EE.1943-7870.0000614	This value compares concentrations measured in an overflow collection device to the water quality measured in the tank. The paper included limited detail on the configuration of the overflow.
Overflow	Thermotolerant coliforms	1.0	van der Sterren, M., Rahman, A., & Dennis, G. R. (2013). Quality and Quantity Monitoring of Five Rainwater Tanks in Western Sydney, Australia. Journal of Environmental Engineering (New York, N.Y.), 139(3), 332–340. https://doi.org/10.1061/(ASCE)EE.1943-7870.0000614	This value compares concentrations measured in an overflow collection device to the water quality measured in the tank. The paper included limited detail on the configuration of the overflow.
Pre-tank filter	Thermotolerant coliforms		Costa, P. C. L. da, Azevedo, A. R. G. de, Silva, F. C. da, Cecchin, D., & Carmo, D. de F. do. (2021). Rainwater treatment using an acrylic blanket as a filtering media. Journal of Cleaner Production, 303, 126964-.	Unable to calculate a value because the target organism was absent in both pre and post-filtration samples

			https://doi.org/10.1016/j.jclepro.2021.126964	
Pre-tank filter	Total coliforms		Costa, P. C. L. da, Azevedo, A. R. G. de, Silva, F. C. da, Cecchin, D., & Carmo, D. de F. do. (2021). Rainwater treatment using an acrylic blanket as a filtering media. Journal of Cleaner Production, 303, 126964-. https://doi.org/10.1016/j.jclepro.2021.126964	Unable to calculate a value because the target organism was absent in both pre and post-filtration samples
Pre-tank filter	Total coliforms	0.5	Taffere, G. R., Beyene, A., Vuai, S. A. H., Gasana, J., & Seleshi, Y. (2017). Dilemma of roof rainwater quality: applications of physical and organic treatment methods in a water scarce region of Mekelle, Ethiopia. Urban Water Journal, 14(5), 460–466. https://doi.org/10.1080/1573062X.2016.1176225	Pre Tank filtration is with a slow-sand filter.
Pre-tank filter and first flush	E. coli	0.1	Amin, M. T., Kim, T. I., Amin, M. N., & Han, M. Y. (2013). Effects of Catchment, First-Flush, Storage Conditions, and Time on Microbial Quality in Rainwater Harvesting Systems. Water Environment Research, 85(12), 2317-2329.	These values are calculated from concentrations estimated from Fig. 3b and are values for system 1. The log reduction value compares sampling point S1,1 with S1,2.
Pre-tank filter and first flush	Fecal coliforms	0.1	Amin, M. T., Kim, T. I., Amin, M. N., & Han, M. Y. (2013). Effects of Catchment, First-Flush, Storage Conditions, and Time on Microbial Quality in Rainwater Harvesting Systems. Water Environment Research, 85(12), 2317-2329.	These values are calculated from concentrations estimated from Fig. 3b and are values for system 1. The log reduction value compares sampling point S1,1 with S1,2.

Pre-tank filter and first flush	Total coliforms	0.1	Amin, M. T., Kim, T. I., Amin, M. N., & Han, M. Y. (2013). Effects of Catchment, First-Flush, Storage Conditions, and Time on Microbial Quality in Rainwater Harvesting Systems. Water Environment Research, 85(12), 2317-2329.	These values are calculated from concentrations estimated from Fig. 3b and are values for system 1. The log reduction value compares sampling point S1,1 with S1,2.
Pre-tank filter and first flush	HPC	0.2	Amin, M. T., Kim, T. I., Amin, M. N., & Han, M. Y. (2013). Effects of Catchment, First-Flush, Storage Conditions, and Time on Microbial Quality in Rainwater Harvesting Systems. Water Environment Research, 85(12), 2317-2329.	These values are calculated from concentrations estimated from Fig. 3b and are values for system 1. The log reduction value compares sampling point S1,1 with S1,2.

APPENDIX B: **Additional papers assessed for information but not included in the table**

Reference	**Exclusion reason**
Ahammed, M. M., & Meera, V. (2010). Metal oxide/hydroxide-coated dual-media filter for simultaneous removal of bacteria and heavy metals from natural waters. Journal of Hazardous Materials, 181(1), 788–793. https://doi.org/10.1016/j.jhazmat.2010.05.082	Post-tank treatment only
Abedin, Md. A., Collins, A. E., Habiba, U., & Shaw, R. (2019). Climate Change, Water Scarcity, and Health Adaptation in Southwestern Coastal Bangladesh. International Journal of Disaster Risk Science, 10(1), 28–42. https://doi.org/10.1007/s13753-018-0211-8	No water quality data
Acharya, S., Datta, R., & Debnath, B. (2023). Theoretical and experimental investigations of an integrated rainwater harvesting system for electricity and drinking water. Environmental Science and Pollution Research International, 30(24), 66359–66371. https://doi.org/10.1007/s11356-023-27120-z	No water quality data
Acharya, S., Datta, R., & Debnath, B. (2023). Theoretical and experimental investigations of an integrated rainwater harvesting system for electricity and drinking water. Environmental Science and Pollution Research International, 30(24), 66359–66371.	No water quality data

https://doi.org/10.1007/s11356-023-27120-z	
Ahmed, W., Huygens, F., Goonetilleke, A., & Gardner, T. (2008). Real-time PCR detection of pathogenic microorganisms in roof-harvested rainwater in Southeast Queensland, Australia. Applied and environmental microbiology, 74(17), 5490–5496. https://doi.org/10.1128/AEM.00331-08	Sampling of existing systems only --- no information on system design
Ahmed, W., Vieritz, A., Goonetilleke, A., & Gardner, T. (2010). Health risk from the use of roof-harvested rainwater in Southeast Queensland, Australia, as potable or nonpotable water, determined using quantitative microbial risk assessment. Applied and environmental microbiology, 76(22), 7382–7391. https://doi.org/10.1128/AEM.00944-10	Sampling of existing systems only --- no information on system design
Alam, K., & Rahman, Md. H. (2019). Post-disaster recovery in the cyclone Aila affected coastline of Bangladesh: women's role, challenges and opportunities. Natural Hazards (Dordrecht), 96(3), 1067–1090. https://doi.org/10.1007/s11069-019-03591-7	No water quality data
Alderton, S. (2020). Tips to harvest rainwater on farm. Farmers Weekly, 173(13), 38–39.	Not peer reviewed
Alegbeleye, O., & Sant'Ana, A. S. (2023). Microbiological quality of irrigation water collected from vegetable farms in Sao Paulo, Brazil during the dry and rainy season. Agricultural Water Management, 279, 108190-. https://doi.org/10.1016/j.agwat.2023.108190	Samples only at one point in the water systems, cannot assess treatment
Alim, M. A., Rahman, A., Tao, Z., Samali, B., Khan, M. M., & Shirin, S. (2020). Feasibility analysis of a small-scale rainwater harvesting system for drinking water production at Werrington, New South Wales, Australia. Journal of Cleaner Production, 270, 122437-. https://doi.org/10.1016/j.jclepro.2020.122437	Simulation study only
Ambast, S. K., Tyagi, N. K., & Raul, S. K. (2006). Management of declining groundwater in the Trans Indo-Gangetic Plain (India): Some options. Agricultural Water Management, 82(3), 279–296. https://doi.org/10.1016/j.agwat.2005.06.005	No rainwater quality data
Amin, M. T., & Han, M. Y. (2009). Roof-harvested rainwater for potable purposes: Application of solar collector disinfection (SOCO-DIS). Water Research (Oxford), 43(20), 5225–5235. https://doi.org/10.1016/j.watres.2009.08.041	Studied solar disinfection - post-tank treatment

Anstiss, R. G., & Ahmed, M. (2007). A Conceptual Model to be Used for Community-based Drinking-water Improvements. Journal of Health, Population and Nutrition, 24(3).	No water quality data - conceptual paper only
Antão- Geraldes, A. M., Pinto, M. F. G. D. A., Afonso, M. J., Albuquerque, A., Calheiros, C., & Silva, F. (2023). Promoting water efficiency in a municipal market building: a case study. Hydrology, 10(3), 69-. https://doi.org/10.3390/hydrology10030069	Modeling study only - no water quality data
Aru Yudhantoro, W., Warno Utomo, S., & Nowo Martono, D. (2020). Water Reuse Planning for Fulfilment of Clean Water in Indonesia. E3S Web of Conferences, 202, 3002-. https://doi.org/10.1051/e3sconf/202020203002	Conference paper - no water quality data
Ashrafuzzaman, M. (2023). Local Context of Climate Change Adaptation in the South-Western Coastal Region of Bangladesh. Sustainability, 15(8), 6664-. https://doi.org/10.3390/su15086664	No water quality data
Ashrafuzzaman, M., Gomes, C., & Guerra, J. (2023). The Changing Climate Is Changing Safe Drinking Water, Impacting Health: A Case in the Southwestern Coastal Region of Bangladesh (SWCRB). Climate (Basel), 11(7), 146-. https://doi.org/10.3390/cli11070146	No water quality data
Bae, S., Maestre, J. P., Kinney, K. A., & Kirisits, M. J. (2019). An examination of the microbial community and occurrence of potential human pathogens in rainwater harvested from different roofing materials. Water research, 159, 406–413. https://doi.org/10.1016/j.watres.2019.05.029	No treatment included -- only roof runoff studied. The paper did exclude the first flush, but this was not compared with later harvested rainwater anywhere in the paper.
Bani, S., Matambo, C., Limson, J., Zuma, B. M., & Tandlich, R. (2024). Operation and Performance of The Lab and Pilotscale Greywater Treatment Systems: Biochar and Gravel Use in South Africa. The Journal of Solid Waste Technology and Management, 50(1), 458–478. https://doi.org/10.5276/jswtm/iswmaw/501/2024.458	Greywater treatment - not rainwater
BUSINESS BRIEFS. (2015). Poultry World, 170(7), 18-.	Not a research paper, no rainwater harvesting data
Castier, M., & de Barros Barreto, P. (2023). Economic attractiveness of domestic rainwater harvesting in Brazilian cities. Discover Water, 3(1), 9–9. https://doi.org/10.1007/s43832-023-00033-1	No water quality data

Chai, H., Chen, Z., Shao, Z., Deng, S., Li, L., Xiang, Y., Li, L., Hu, X., & He, Q. (2019). Long-term pollutant removal performance and mitigation of rainwater quality deterioration with ceramsite and Cyperus alternifolius in mountainous cities of China. Environmental Science and Pollution Research International, 26(32), 32993–33003. https://doi.org/10.1007/s11356-019-06328-y	No microbial water quality data
Chamberlain, J. F., & Sabatini, D. A. (2014). Water-supply options in arsenic-affected regions in Cambodia: Targeting the bottom income quintiles. The Science of the Total Environment, 488–489, 521–531. https://doi.org/10.1016/j.scitotenv.2013.12.011	No water quality data
Chen Qiuli, Sun Hongwei, & Chen Shiguang. (2021). Performance of an innovative gravity-driven micro-filtration technology for roof rainwater treatment. Environmental Engineering Research, 26(6), 20–28.	Studied ceramic filter - post-tank treatment
Chen, C.-F., Chen, Y.-W., Lin, C.-H., & Lin, J.-Y. (2024). Field performance of 15 rain gardens in different cities in Taiwan. The Science of the Total Environment, 947, 174545-. https://doi.org/10.1016/j.scitotenv.2024.174545	Samples only at one point in the water systems, cannot assess treatment
Chidamba, L., & Korsten, L. (2015). Pyrosequencing analysis of roof-harvested rainwater and river water used for domestic purposes in Luthengele village in the Eastern Cape Province of South Africa. Environmental Monitoring and Assessment, 187(2), 41–17. https://doi.org/10.1007/s10661-014-4237-0	Single samples only from systems
Chidamba, L., & Korsten, L. (2018). Relative proportions of E. coli and Enterococcus spp. may be a good indicator of potential health risks associated with the use of roof harvested rainwater stored in tanks. Environmental monitoring and assessment, 190(3), 177. https://doi.org/10.1007/s10661-018-6554-1	Sampling of existing systems only --- no information on system design
Chubaka, C. E., Whiley, H., Edwards, J. W., & Ross, K. E. (2018). Lead, Zinc, Copper, and Cadmium Content of Water from South Australian Rainwater Tanks. International Journal of Environmental Research and Public Health, 15(7), 1551-. https://doi.org/10.3390/ijerph15071551	Small amount of samples looked at pre and post filter, but not enough data given to calculate percent reductions

Chubaka, C. E., Whiley, H., Edwards, J. W., & Ross, K. E. (2018). Microbiological Values of Rainwater Harvested in Adelaide. Pathogens (Basel), 7(1), 21-. https://doi.org/10.3390/pathogens7010021	Contained data from samples before and after post-tank filtration systems on multiple homes, but no information was given on the filtration, unclear if it was just filters or if it included UV or similar
Clark, G. G., Jamal, R., & Weidhaas, J. (2019). Roofing material and irrigation frequency influence microbial risk from consuming homegrown lettuce irrigated with harvested rainwater. The Science of the total environment, 651(Pt 1), 1011–1019. https://doi.org/10.1016/j.scitotenv.2018.09.277	Direct sampling of roof runoff only
D' Silva, T. C., Verma, S., Magdaline, R. M., Chandra, R., & Khan, A. A. (2022). Environmental resilience and sustainability through green technologies: A case evidence from rural coastal India. Environmental Engineering Research, 27(5), 210262-. https://doi.org/10.4491/eer.2021.262	Computational only, no water quality data
de Kwaadsteniet, M., Dobrowsky, P. H., van Deventer, A., Khan, W., & Cloete, T. E. (2013). Domestic Rainwater Harvesting: Microbial and Chemical Water Quality and Point-of-Use Treatment Systems. Water, Air, and Soil Pollution, 224(7), 1–19. https://doi.org/10.1007/s11270-013-1629-7	Review paper only
Delaney, R. G., Blackburn, G. A., Whyatt, J. D., & Folkard, A. M. (2022). SiteFinder: A geospatial scoping tool to assist the siting of external water harvesting structures. Agricultural Water Management, 272, 107836-. https://doi.org/10.1016/j.agwat.2022.107836	No water quality data - modeling study
Demuzere, M., Coutts, A. M., Göhler, M., Broadbent, A. M., Wouters, H., van Lipzig, N. P. M., & Gebert, L. (2014). The implementation of biofiltration systems, rainwater tanks and urban irrigation in a single-layer urban canopy model. Urban Climate, 10, 148–170. https://doi.org/10.1016/j.uclim.2014.10.012	No water quality data
Diehl de Souza, T., & Ghisi, E. (2020). Harvesting rainwater from scaffolding platforms and walls to reduce potable water consumption at buildings construction sites. Journal of Cleaner Production, 258, 120909-. https://doi.org/10.1016/j.jclepro.2020.120909	Modeling study only - no water quality data

Dissanayake, J., & Han, M. (2021). The effect of number of tanks on water quality in rainwater harvesting systems under sudden contaminant input. The Science of the Total Environment, 769, 144553-. https://doi.org/10.1016/j.scitotenv.2020.144553	experimental study using kaolin clay or salt as a tracer - no microbial data
Dobrowsky, P. H., Khan, S., Cloete, T. E., & Khan, W. (2016). Molecular detection of Acanthamoeba spp., Naegleria fowleri and Vermamoeba (Hartmannella) vermiformis as vectors for Legionella spp. in untreated and solar pasteurized harvested rainwater. Parasites & Vectors, 9(1), 539–539. https://doi.org/10.1186/s13071-016-1829-2	Studied solar pasteurization, post tank treatment only
Dobrowsky, P. H., Lombard, M., Cloete, W. J., Saayman, M., Cloete, T. E., Carstens, M., Khan, S., & Khan, W. (2015). Efficiency of Microfiltration Systems for the Removal of Bacterial and Viral Contaminants from Surface and Rainwater. Water, Air, and Soil Pollution, 226(3), 1–14. https://doi.org/10.1007/s11270-015-2317-6	Post-tank treatment only
Doyle, K., & Shanahan, P. (2010, November). The impact of first flush removal on rainwater quality and rainwater harvesting systems' reliability in rural Rwanda. In World Environmental and Water Resources Congress 2010: Challenges of Change (pp. 465-474).	Conference paper only
Du, X., Ma, R., Liang, Z., Kuang, K., Chu, L., Liu, L., Song, W., & Tian, J. (2023). Flux Improvement and Biofilm Performance of an Oblique Gravity-Driven Ceramic Membrane Bioreactor Coupled with Electrocoagulation for Roofing Rainwater Purification. ACS ES&T Engineering, 3(11), 1813–1825. https://doi.org/10.1021/acsestengg.3c00236	Studied post tank treatment only
Du, X., Ma, R., Xiao, M., Song, W., Tan, Y., Wang, Z., Ng, A. H.-M., & Zhang, W. (2022). Integrated electro-coagulation and gravity driven ceramic membrane bioreactor for roofing rainwater purification: Flux improvement and extreme operating case. The Science of the Total Environment, 851, 158197–158197. https://doi.org/10.1016/j.scitotenv.2022.158197	Studied post tank treatment only
Du, X., Wang, Z., Liu, Y., Ma, R., Lu, S., Lu, X., Liu, L., & Liang, H. (2022). Gravity-driven membrane bioreactor coupled with electrochemical oxidation disinfection (GDMBR-EO) to treat roofing rainwater. Chemical Engineering Journal (Lausanne, Switzerland : 1996), 427, 131714-. https://doi.org/10.1016/j.cej.2021.131714	Studied gravity-driven membrane bioreactor-post tank treatment only

Du, X., Xu, J., Mo, Z., Luo, Y., Su, J., Nie, J., Wang, Z., Liu, L., & Liang, H. (2019). The performance of gravity-driven membrane (GDM) filtration for roofing rainwater reuse: Implications of roofing rainwater energy and rainwater purification. The Science of the Total Environment, 697, 134187–134187. https://doi.org/10.1016/j.scitotenv.2019.134187	Membrane filtration -- post tank treatment only
Ekowati, S. D., & Hadi, S. P. (2020). Multi Effect of Rain Harvesting in the Floating Village of Malahing on the Coast Bontang Developed by the CSR of PKT. IOP Conference Series. Earth and Environmental Science, 448(1), 12129-. https://doi.org/10.1088/1755-1315/448/1/012129	Conference paper - no water quality data
Evans, C. A., Coombes, P. J., Dunstan, R. H., & Harrison, T. (2009). Extensive bacterial diversity indicates the potential operation of a dynamic micro-ecology within domestic rainwater storage systems. Science of the Total Environment, 407(19), 5206-5215.	Rainwater quality data from only one point in the system
Evans, C. A., Coombes, P. J., Dunstan, R. H., & Harrison, T. (2009). Extensive bacterial diversity indicates the potential operation of a dynamic micro-ecology within domestic rainwater storage systems. The Science of the total environment, 407(19), 5206–5215. https://doi.org/10.1016/j.scitotenv.2009.06.009	Tap samples only - no possibility to calculate reductions
Evans, C. A., Coombes, P. J., Dunstan, R. H., Harrison, T., Martin, A., & Harris, J. N. (2006). Coliforms, biofilms, microbial diversity and the quality of roof-harvested rainwater. Water Res, 40(1), 34-44.	Samples taken in two locations from tanks, but no clear treatment step from Standard 63 between them "For the determination of tank water bacterial counts, samples were collected both from within the tank, by submerging a sterile container 30 cm below the water surface, as well as from the tap outlet connected directly to the tank"
Farrell, A., Swan, D. A., & R. Mendes, D. R. L. (2021). Rainwater Harvesting in the Rainforest: A Technical and Socioeconomic Review of Community Approaches in Brazil. IOP Conference Series. Materials Science and Engineering, 1196(1), 12003-. https://doi.org/10.1088/1757-899X/1196/1/012003	Conference paper

Farreny, R., Morales-Pinzón, T., Guisasola, A., Tayà, C., Rieradevall, J., & Gabarrell, X. (2011). Roof selection for rainwater harvesting: Quantity and quality assessments in Spain. Water Research (Oxford), 45(10), 3245–3254. https://doi.org/10.1016/j.watres.2011.03.036	physicochemical quality only
Feng, W., Hatt, B. E., McCarthy, D. T., Fletcher, T. D., & Deletic, A. (2012). Biofilters for Stormwater Harvesting: Understanding the Treatment Performance of Key Metals That Pose a Risk for Water Use. Environmental Science & Technology, 46(9), 5100–5108. https://doi.org/10.1021/es203396f	No microbial water quality data
Fraga, B. D., Maldonado, M. U., & Miguel, P. A. C. (2018). Mapeamento da produção tecnológica sobre aproveitamento de água da chuva: uma análise bibliométrica a partir de patentes. Revista Produção Online, 18(4), 1279–1300. https://doi.org/10.14488/1676-1901.v18i4.2827	No water quality data
Galvis, A., Zambrano, D. A., van der Steen, N. P., & Gijzen, H. J. (2014). Evaluation of pollution prevention options in the municipal water cycle. Journal of Cleaner Production, 66, 599–609. https://doi.org/10.1016/j.jclepro.2013.10.057	Computational only - no sampling
Gao, Z., Zhang, Q., Li, J., Wang, Y., Dzakpasu, M., & Wang, X. C. (2023). First flush stormwater pollution in urban catchments: A review of its characterization and quantification towards optimization of control measures. Journal of Environmental Management, 340, 117976–117976. https://doi.org/10.1016/j.jenvman.2023.117976	Review paper
Gao, Z., Zhang, Q., Wang, Y., Dzakpasu, M., & Wang, X. C. (2024). Contaminant distribution and migration in roofing rainwater: Implications for sustainable utilization and pollution control. Journal of Water Process Engineering, 61, 105298-. https://doi.org/10.1016/j.jwpe.2024.105298	No microbial water quality data
Gee, K. D., Schimoler, D., Charron, B. T., Woodward, M. D., & Hunt, W. F. (2021). A Comparison of Methods to Address Anaerobic Conditions in Rainwater Harvesting Systems. Water (Basel), 13(23), 3419-. https://doi.org/10.3390/w13233419	No microbial water quality data
Ghura, A. S., & Abhishek. (2023). VARDHMAN ENVIROTECH: CREATING BLUE OCEAN AND REINVENTING BUSINESS MODEL. Asian Case Research Journal, 27(3), 253–263. https://doi.org/10.1142/S0218927523500165	No water quality data

Glick, R., Jeong, J., Srinivasan, R., Arnold, J. G., & Her, Y. (2023). Adaptation of SWAT Watershed Model for Stormwater Management in Urban Catchments: Case Study in Austin, Texas. Water (Basel), 15(9), 1770-. https://doi.org/10.3390/w15091770	No water quality data- simulation study
Grabowski, T., Bochniak, A., Siwiec, T., & Jóźwiakowski, K. (2024). Pollutant Removal Efficiency in a Rainwater Treatment System in Roztocze National Park (Poland). Sustainability, 16(11), 4709-. https://doi.org/10.3390/su16114709	Post-tank treatment only
Grabowski, T., Jóźwiakowski, K., Bochniak, A., Stachyra, P., & Radliński, B. (2023). Assessment of Rainwater Quality Regarding its Use in The Roztocze National Park (Poland)—Case Study. Applied Sciences, 13(10), 6110-. https://doi.org/10.3390/app13106110	Water quality data at only one point -- just roof runoff- no ability to assess treatment
Gregory, E. C., & Victor, N. U. (2018). Impact of Proliferation of Borehole Development Projects on Groundwater Quality in Abia State, Nigeria. International Journal of Biosciences and Technology, 11(2), 20–29.	No rainwater harvesting data
Hafizi Md Lani, N., Yusop, Z., & Syafiuddin, A. (2018). A Review of Rainwater Harvesting in Malaysia: Prospects and Challenges. Water (Basel), 10(4), 506-. https://doi.org/10.3390/w10040506	No rainwater quality data - review paper
Halim, Z., Din, A., Tokit, E., & Rosli, M. (2019). Development of Rainwater Harvesting System for Sekolah Menengah Kebangsaan Iskandar Syah Melaka. IOP Conference Series. Earth and Environmental Science, 268(1), 12024-. https://doi.org/10.1088/1755-1315/268/1/012024	Conference paper only
Hameed, A., Arooj, F., Luqman, M., Kashif, S. ur R., Iftikhar, A., Aziz ur Rehman, S., Najeeb, I., & Ahmed Somroo, Z. (2022). Assessment of Filtration System Efficiency of Artificial Groundwater Recharge wells in Lahore. Polish Journal of Environmental Studies, 31(3), 2625–2636. https://doi.org/10.15244/pjoes/143921	Examined specially designed filter system for groundwater recharge - not applicable to ARCSA standard
Hammes, G., Thives, L. P., & Ghisi, E. (2018). Application of stormwater collected from porous asphalt pavements for non-potable uses in buildings. Journal of Environmental Management, 222, 338–347. https://doi.org/10.1016/j.jenvman.2018.05.094	Filtration was porous pavers - not included in Standard 63

Harun, M. A. Y. A., & Kabir, G. M. M. (2013). Evaluating pond sand filter as sustainable drinking water supplier in the Southwest coastal region of Bangladesh. Applied Water Science, 3(1), 161–166. https://doi.org/10.1007/s13201-012-0069-7	No rainwater harvesting data
Hassan, M. M. (2005). Arsenic poisoning in Bangladesh: spatial mitigation planning with GIS and public participation. Health Policy (Amsterdam), 74(3), 247–260. https://doi.org/10.1016/j.healthpol.2005.01.008	No rainwater harvesting data
Heidy Gabriela, R. M., & Jose Vladimir, C. T. (2022). Rainwater harvesting system as a strategy for adaptation on climate change: A review. IOP Conference Series. Earth and Environmental Science, 1121(1), 12007-. https://doi.org/10.1088/1755-1315/1121/1/012007	Conference paper - review paper
Helmreich, B., & Horn, H. (2009). Opportunities in rainwater harvesting. Desalination, 248(1), 118–124. https://doi.org/10.1016/j.desal.2008.05.046	Review paper only
Hoque, B. A., Hoque, M. M., Ahmed, T., Islam, S., Azad, A. K., Ali, N., Hossain, M., & Hossain, M. S. (2004). Demand-based water options for arsenic mitigation: an experience from rural Bangladesh. Public Health (London), 118(1), 70–77. https://doi.org/10.1016/S0033-3506(03)00135-5	review paper
Hossain, M., Rahman, S. N., Bhattacharya, P., Jacks, G., Saha, R., & Rahman, M. (2015). Sustainability of arsenic mitigation interventions—an evaluation of different alternative safe drinking water options provided in Matlab, an arsenic hot spot in Bangladesh. Frontiers in Environmental Science, 3(30). https://doi.org/10.3389/fenvs.2015.00030	No water quality data from rainwater harvesting
Howard, G., Ahmed, M. F., Shamsuddin, A. J., Mahmud, S. G., & Deere, D. (2007). Risk Assessment of Arsenic Mitigation Options in Bangladesh. Journal of Health, Population and Nutrition, 24(3).	No rainwater harvesting water quality data
Hussain, F., Hussain, R., Wu, R.-S., & Abbas, T. (2019). Rainwater Harvesting Potential and Utilization for Artificial Recharge of Groundwater Using Recharge Wells. Processes, 7(9), 623-. https://doi.org/10.3390/pr7090623	No water quality data from rainwater harvesting
Hussain, M. D., & Ziauddin, A. T. M. (1992). Rainwater harvesting and storage techniques from Bangladesh. Waterlines, 10(3), 10–12. https://doi.org/10.3362/0262-8104.1992.003	No water quality data from rainwater harvesting

Im, J., & Yoon, J. (2024). Promoting Green Infrastructure Awareness through Education: Pre- and Post-Assessments of Its Effectiveness. Landscape Journal, 43(1), 49–68. https://doi.org/10.3368/lj.43.1.49	No water quality data from rainwater harvesting
Inauen, J., Hossain, M. M., Johnston, R. B., & Mosler, H.-J. (2013). Acceptance and use of eight arsenic-safe drinking water options in Bangladesh. PloS One, 8(1), e53640-. https://doi.org/10.1371/journal.pone.0053640	No water quality data from rainwater harvesting
Islam, Md. A., Karim, Md. R., Higuchi, T., Sakakibara, H., & Sekine, M. (2014). Comparison of the trace metal concentration of drinking water supply options in southwest coastal areas of Bangladesh. Applied Water Science, 4(2), 183–191. https://doi.org/10.1007/s13201-013-0140-z	Samples only at one point in the system
Jaiyeola, A. T. (2017). The management and treatment of airport rainwater in a water-scarce environment. International Journal of Environmental Science and Technology (Tehran), 14(2), 421–434. https://doi.org/10.1007/s13762-016-1122-0	No water quality data
Jakariya, M., Rahman, M. M., Mahzabin, L., Chowdhury, A., Adiba, H., Alam, Md. S., Murshed, M. F., Sonne, C., Barceló, D., Chen, J., Islam, Md. A., & Bhattacharya, P. (2024). Changing water sources and extraction methods in Bangladesh: Challenges, consequences, and sustainable solutions. Groundwater for Sustainable Development, 25, 101129-. https://doi.org/10.1016/j.gsd.2024.101129	No water quality data
James, D. (2020). What's in Your Livestock Shed? Farmers Weekly, 173(11), 30–31.	Not peer-reviewed
Jiang, Y., Yuan, Y., & Piza, H. (2015). A Review of Applicability and Effectiveness of Low Impact Development/Green Infrastructure Practices in Arid/Semi-Arid United States. Environments (Basel, Switzerland), 2(4), 221–249. https://doi.org/10.3390/environments2020221	review paper
Jing, X., Zhang, S., Zhang, J., Wang, Y., & Wang, Y. (2017). Assessing efficiency and economic viability of rainwater harvesting systems for meeting non-potable water demands in four climatic zones of China. Resources, Conservation and Recycling, 126, 74–85. https://doi.org/10.1016/j.resconrec.2017.07.027	Computational only - no sampling

Jones, T. R., Poitras, J., Levett, A., Langendam, A., Vietti, A., & Southam, G. (2023). Accelerated carbonate biomineralisation of Venetia diamond mine coarse residue deposit (CRD) material – A field trial study. The Science of the Total Environment, 893, 164853–164853. https://doi.org/10.1016/j.scitotenv.2023.164853	Not about rainwater harvesting
Jordan, F. L., Seaman, R., Riley, J. J., & Yoklic, M. R. (2008). Effective removal of microbial contamination from harvested rainwater using a simple point of use filtration and UV-disinfection device. Urban Water Journal, 5(3), 209-218.	Single samples only from systems
Judeh, T., Shahrour, I., & Comair, F. (2022). Smart Rainwater Harvesting for Sustainable Potable Water Supply in Arid and Semi-Arid Areas. Sustainability, 14(15), 9271-. https://doi.org/10.3390/su14159271	Modeling study only - no water quality data
Julien, R., Dreelin, E., Whelton, A. J., Lee, J., Aw, T. G., Dean, K., & Mitchell, J. (2020). Knowledge gaps and risks associated with premise plumbing drinking water quality. AWWA Water Science, 2(3). https://doi.org/10.1002/aws2.1177	No water quality samples
Karima, A., & Shafiul Islam, Kh. M. (2020). Drinking water desalination using low-cost Tubular Solar Still. Applied Water Science, 10(1), 1–6. https://doi.org/10.1007/s13201-019-1093-7	No water quality data from rainwater harvesting
Kasmin, H., Bakar, N. H., & Zubir, M. M. (2016). Monitoring on The Quality and Quantity of DIY Rainwater Harvesting System. IOP Conference Series. Materials Science and Engineering, 136(1), 12067–12074. https://doi.org/10.1088/1757-899X/136/1/012067	Conference paper
Keithley, S. E., Fakhreddine, S., Kinney, K. A., & Kirisits, M. J. (2018). Effect of Treatment on the Quality of Harvested Rainwater for Residential Systems. Journal - American Water Works Association, 110(7), E1–E11. https://doi.org/10.1002/awwa.1054	Post-tank treatment only
Khan, Md. S., & Paul, S. K. (2023). Fresh water management in coastal Bangladesh: preparedness and adaptation. Discover Water, 3(1), 27–14. https://doi.org/10.1007/s43832-023-00052-y	Surveys only, no rainwater harvesting data
Kim, J. E., Humphrey, D., & Hofman, J. (2022). Evaluation of harvesting urban water resources for sustainable water management: Case study in Filton Airfield, UK. Journal of Environmental Management, 322, 116049–116049. https://doi.org/10.1016/j.jenvman.2022.116049	Samples only at one point in the system

Kim, T., Lye, D., Donohue, M., Mistry, J. H., Pfaller, S., Vesper S., & Kiristis, M. J. (2016). Harvested Rainwater Quality Before and After Treatment and Distribution in Residential Systems. Journal - American Water Works Association, 108(11), E571–E584. https://doi.org/10.5942/jawwa.2016.108.0182	Post-tank treatment only
Köster, S., Hadler, G., Opitz, L., & Thoms, A. (2023). Using Stormwater in a Sponge City as a New Wing of Urban Water Supply—A Case Study. Water (Basel), 15(10), 1893-. https://doi.org/10.3390/w15101893	Post-tank treatment only
Kucukkaya, E., Kelesoglu, A., Gunaydin, H., Kilic, G. A., & Unver, U. (2021). Design of a passive rainwater harvesting system with green building approach. International Journal of Sustainable Energy, 40(2), 175–187. https://doi.org/10.1080/14786451.2020.1801681	No water quality data
Kuller, M., Dolman, N. J., Vreeburg, J. H. G., & Spiller, M. (2017). Scenario analysis of rainwater harvesting and use on a large scale - assessment of runoff, storage and economic performance for the case study Amsterdam Airport Schiphol. Urban Water Journal, 14(3), 237–246. https://doi.org/10.1080/1573062X.2015.1086007	No water quality data
Kus, B., Kandasamy, J., Vigneswaran, S., & Shon, H. K. (2010). Analysis of first flush to improve the water quality in rainwater tanks. Water science and technology : a journal of the International Association on Water Pollution Research, 61(2), 421–428. https://doi.org/10.2166/wst.2010.823	Recorded water quality data in runoff through time -- no sampling of multiple points in a rainwater system
Lakshminarayana, S. V., Sathian, K. K., & Prakash, K. A. (2017). Performance Evaluation of First Flush with Micromesh Filter System under Actual Rainfall Condition. Int. J. Curr. Microbiol. App. Sci, 6(3), 292-300.	No microbial data, small prototype of a system using mesh (60 micron and smaller) for filtration
Lay, J. J., Vogel, J. R., Belden, J. B., Brown, G. O., & Storm, D. E. (2024). Water Quality and the First-Flush Effect in Roof-Based Rainwater Harvesting, Part I: Water Quality and Soil Accumulation. Water (Basel), 16(10), 1402-. https://doi.org/10.3390/w16101402	Single sample location only from systems
Lay, J. J., Vogel, J. R., Belden, J. B., Brown, G. O., & Storm, D. E. (2024). Water Quality and the First-Flush Effect in Roof-Based Rainwater Harvesting, Part II: First Flush. Water (Basel), 16(10), 1421-. https://doi.org/10.3390/w16101421	No microbial data presented

Leong, J. Y. C., Chong, M. N., & Poh, P. E. (2018). Assessment of greywater quality and performance of a pilot-scale decentralised hybrid rainwater-greywater system. Journal of Cleaner Production, 172, 81–91. https://doi.org/10.1016/j.jclepro.2017.10.172	Greywater samples only
Leong, J. Y. C., Oh, K. S., Poh, P. E., & Chong, M. N. (2017). Prospects of hybrid rainwater-greywater decentralised system for water recycling and reuse: A review. Journal of Cleaner Production, 142, 3014–3027. https://doi.org/10.1016/j.jclepro.2016.10.167	Review paper
Lepcha, R., Kumar Patra, S., Ray, R., Thapa, S., Baral, D., & Saha, S. (2024). Rooftop rainwater harvesting a solution to water scarcity: A review. Groundwater for Sustainable Development, 26, 101305-. https://doi.org/10.1016/j.gsd.2024.101305	Review paper only
Ley, C. J., Proctor, C. R., Jordan, K., Ra, K., Noh, Y., Odimayomi, T., Julien, R., Kropp, I., Mitchell, J., Nejadhashemi, A. P., Whelton, A. J., & Aw, T. G. (2020). Impacts of Municipal Water–Rainwater Source Transitions on Microbial and Chemical Water Quality Dynamics at the Tap. Environmental Science & Technology, 54(18), 11453–11463. https://doi.org/10.1021/acs.est.0c03641	All samples taken after the tank - no data available for comparison
Liu, L., Fu, Y., Wei, Q., Liu, Q., Wu, L., Wu, J., & Huo, W. (2019). Applying Bio-Slow Sand Filtration for Water Treatment. Polish Journal of Environmental Studies, 28(4), 2243–2251. https://doi.org/10.15244/pjoes/89544	Not about rainwater harvesting
Liu, S., Xia, S., Zhang, X., Cai, X., Yang, J., Hu, Y., Zhou, S., & Wang, H. (2024). Microbial communities exhibit distinct diversities and assembly mechanisms in rainwater and tap-water storage systems. Water Research (Oxford), 253, 121305–121305. https://doi.org/10.1016/j.watres.2024.121305	Single samples only from systems
López-Ballesteros, A., Trolle, D., Srinivasan, R., & Senent-Aparicio, J. (2023). Assessing the effectiveness of potential best management practices for science-informed decision support at the watershed scale: The case of the Mar Menor coastal lagoon, Spain. The Science of the Total Environment, 859(Pt 1), 160144-. https://doi.org/10.1016/j.scitotenv.2022.160144	Simulation only
MacDonald, R. (2001). Providing clean water: lessons from Bangladesh. BMJ, 322(7287), 626–627. https://doi.org/10.1136/bmj.322.7287.626	Editorial, not a research paper, no rainwater harvesting data

Malekinezhad, H., Sepehri, M., Hosseini, S. Z., Santos, C. A. G., Rodrigo-Comino, J., & Meshram, S. G. (2021). Role and Concept of Rooftop Disconnection in Terms of Runoff Volume and Flood Peak Quantity. International Journal of Environmental Research, 15(6), 935–946. https://doi.org/10.1007/s41742-021-00355-9	No water quality samples
Maniam, G., Zakaria, N. A., Leo, C. P., Vassilev, V., Blay, K. B., Behzadian, K., & Poh, P. E. (2022). An assessment of technological development and applications of decentralized water reuse: A critical review and conceptual framework. Wiley Interdisciplinary Reviews. Water, 9(3), e1588-n/a. https://doi.org/10.1002/wat2.1588	review paper only
Mao, J., Xia, B., Zhou, Y., Bi, F., Zhang, X., Zhang, W., & Xia, S. (2021). Effect of roof materials and weather patterns on the quality of harvested rainwater in Shanghai, China. Journal of Cleaner Production, 279, 123419-. https://doi.org/10.1016/j.jclepro.2020.123419	physicochemical quality only
Martinson, B., & Thomas, T. (2009). Quantifying the first-flush phenomenon: effects of first-flush on water yield and quality. In 14th International Rainwater Catchment Systems Conference.	Conference paper only
Marwa, J., Lufingo, M., Noubactep, C., & Machunda, R. (2018). Defeating Fluorosis in the East African Rift Valley: Transforming the Kilimanjaro into a Rainwater Harvesting Park. Sustainability, 10(11), 4194-. https://doi.org/10.3390/su10114194	No water quality data
Melo Neto, M. G. de, Freitas, B. L. S., Fava, N. N. M., & Sabogal-Paz, L. P. (2024). Rainwater treatment system efficiency: Household slow sand filter combined with UVC lamp disinfection. Journal of Water Process Engineering, 58, 104785-. https://doi.org/10.1016/j.jwpe.2024.104785	post tank treatment only, inoculated the rainwater with E coli for testing
Mercer, N., & Hanrahan, M. (2017). “Straight from the heavens into your bucket”: domestic rainwater harvesting as a measure to improve water security in a subarctic indigenous community. International Journal of Circumpolar Health, 76(1), 1312223–1312229. https://doi.org/10.1080/22423982.2017.1312223	water consumption only, no water quality data
Miazga, M. (2012). Creatively green. PM Engineer, 18(4), 16-.	Not peer reviewed, no rainwater harvesting water quality data

Millan, M. I. P., Yanez Pacios, R. T., Garcia, A. C., & Pico, A. S. (2016). Energy Performance Improvement And Cultural Enhancement Of The Andalusian Rural Heritage: Case Study - “El Cortijo Del Fraile.” WIT Transactions on the Built Environment, 161, 59–70. https://doi.org/10.2495/ARC160061	No rainwater harvesting water quality data, concept only
Moon, S.-H., Lee, J.-Y., Lee, B.-J., Park, K.-H., & Jo, Y.-J. (2012). Quality of harvested rainwater in artificial recharge site on Jeju volcanic island, Korea. Journal of Hydrology (Amsterdam), 414, 268–277. https://doi.org/10.1016/j.jhydrol.2011.10.041	Chemical water quality only
Moore, T. L. C., & Hunt, W. F. (2013). Predicting the carbon footprint of urban stormwater infrastructure. Ecological Engineering, 58, 44–51. https://doi.org/10.1016/j.ecoleng.2013.06.021	No water quality data
Morales-Figueroa, C., Castillo-Suárez, L. A., Linares-Hernández, I., Martínez-Miranda, V., & Teutli-Sequeira, E. A. (2023). Treatment processes and analysis of rainwater quality for human use and consumption regulations, treatment systems and quality of rainwater. International Journal of Environmental Science and Technology (Tehran), 20(8), 9369–9392. https://doi.org/10.1007/s13762-023-04802-2	review paper only
Mowla, Q. A., & Kabir, S. T. D. (2020). Production of Concrete Using Diverted Rainwater First Flush. IOP Conference Series. Earth and Environmental Science, 581(1), 12027-. https://doi.org/10.1088/1755-1315/581/1/012027	Conference paper
Muftiah Ridjal, A. T., Dewi, C., & Febriany, I. A. (2023). Navigating Clean Water Scarcity: Assessing Household Behaviour of Clean Water Treatment and Storage in Tallo, Makassar. IOP Conference Series. Earth and Environmental Science, 1275(1), 12048-. https://doi.org/10.1088/1755-1315/1275/1/012048	Conference paper and no water quality data
Muktiningsih, S. D., & Putri, D. M. A. R. M. S. (2021). Study of the potential use of rainwater as clean water with simple media gravity filters: A review. IOP Conference Series. Earth and Environmental Science, 733(1), 12147-. https://doi.org/10.1088/1755-1315/733/1/012147	review paper only
Nachshon, U., Ben-Hur, M., Kurtzman, D., Katzir, R., Netzer, L., Gusser, G., & Livshitz, Y. (2021). Dynamic Release of Solutes from Roof Bitumen Sheets Used for Rainwater Harvesting. Water (Basel), 13(24), 3496-. https://doi.org/10.3390/w13243496	physicochemical quality only

Naddeo, V., Scannapieco, D., & Belgiorno, V. (2013). Enhanced drinking water supply through harvested rainwater treatment. Journal of Hydrology (Amsterdam), 498, 287–291. https://doi.org/10.1016/j.jhydrol.2013.06.012	Post-tank treatment only
Naser, A. M., Martorell, R., Narayan, K. M. V., & Clasen, T. F. (2017). First Do No Harm: The Need to Explore Potential Adverse Health Implications of Drinking Rainwater. Environmental Science & Technology, 51(11), 5865–5866. https://doi.org/10.1021/acs.est.7b01886	Viewpoint article, not research
Naus, F. L., Burer, K., van Laerhoven, F., Griffioen, J., Ahmed, K. M., & Schot, P. (2020). Why Do People Remain Attached to Unsafe Drinking Water Options? Quantitative Evidence from Southwestern Bangladesh. Water (Basel), 12(2), 342-. https://doi.org/10.3390/w12020342	No water quality data
Nawaz, M. H., & Baig, M. A. (2018). Domestic three stage water-treatment option for harvested rainwater in water-stressed communities. IOP Conference Series. Materials Science and Engineering, 414(1), 12030-. https://doi.org/10.1088/1757-899X/414/1/012030	Conference paper - review paper
Ndé-Tchoupé, A. I., Nanseu-Njiki, C. P., Hu, R., Nassi, A., Noubactep, C., & Licha, T. (2019). Characterizing the reactivity of metallic iron for water defluoridation in batch studies. Chemosphere (Oxford), 219, 855–863. https://doi.org/10.1016/j.chemosphere.2018.12.065	No rainwater harvesting water quality data
Ndé-Tchoupé, A., Tepong-Tsindé, R., Lufingo, M., Pembe-Ali, Z., Lugodisha, I., Mureth, R., Nkinda, M., Marwa, J., Gwenzi, W., Mwamila, T., Rahman, M., Noubactep, C., & Njau, K. (2019). White Teeth and Healthy Skeletons for All: The Path to Universal Fluoride-Free Drinking Water in Tanzania. Water (Basel), 11(1), 131-. https://doi.org/10.3390/w11010131	No rainwater harvesting water quality data, concept only
Nguyen, D. C., Dao, A. D., Kim, T.-I., & Han, M. (2013). A Sustainability Assessment of the Rainwater Harvesting System for Drinking Water Supply: A Case Study of Cukhe Village, Hanoi, Vietnam. Environmental Engineering Research, 18(2), 109–114. https://doi.org/10.4491/eer.2013.18.2.109	Samples only at one point in the water systems, cannot assess treatment

Nnaji, C. C., Emenike, P. C., & Tenebe, I. T. (2017). An Optimization Approach for Assessing the Reliability of Rainwater Harvesting. Water Resources Management, 31(6), 2011–2024. https://doi.org/10.1007/s11269-017-1630-9	Modeling study only - no water quality data
Nolde, E. (2007). Possibilities of rainwater utilisation in densely populated areas including precipitation runoffs from traffic surfaces. Desalination, 215(1), 1–11. https://doi.org/10.1016/j.desal.2006.10.033	Stormwater harvesting, not rainwater, post-tank treatment
Nosrati, K. (2017). Identification of a water quality indicator for urban roof runoff. Sustainability of Water Quality and Ecology, 9–10, 78–87. https://doi.org/10.1016/j.swaqe.2017.07.001	No microbial water quality data
Oviedo-Ocaña, E. R., Dominguez, I., Ward, S., Rivera-Sanchez, M. L., & Zaraza-Peña, J. M. (2018). Financial feasibility of end-user designed rainwater harvesting and greywater reuse systems for high water use households. Environmental Science and Pollution Research International, 25(20), 19200–19216. https://doi.org/10.1007/s11356-017-8710-5	No rainwater harvesting water quality data, concept only, financial only
Oyebode, O. J., & Umar, A. M. (2024). Design and Modelling of Urban Stormwater Management and Treatment Infrastructure for Communities in Wuse, Abuja. Nature Environment and Pollution Technology, 23(1), 69–86. https://doi.org/10.46488/NEPT.2024.v23i01.005	No microbial data, small prototype of a system using memory foam for filtration
Palawat, K., Root, R. A., Cortez, L. I., Foley, T., Carella, V., Beck, C., & Ramírez-Andreotta, M. D. (2023). Patterns of contamination and burden of lead and arsenic in rooftop harvested rainwater collected in Arizona environmental justice communities. Journal of Environmental Management, 337, 117747–117747. https://doi.org/10.1016/j.jenvman.2023.117747	physicochemical quality only
Pembe-Ali, Z., Mwamila, T. B., Lufingo, M., Gwenzi, W., Marwa, J., Rwiza, M. J., Lugodisha, I., Qi, Q., & Noubactep, C. (2021). Application of the Kilimanjaro Concept in Reversing Seawater Intrusion and Securing Water Supply in Zanzibar, Tanzania. Water (Basel), 13(15), 2085-. https://doi.org/10.3390/w13152085	No water quality data
Peng, Y., Zhang, Z., Yao, J.-J., Zhou, Y., Cai, S., Zhang, J., Li, Y., Kong, Y., & Zhang, W. (2019). Computation fluid dynamics model of first-flush runoff through a hydrodynamic separator. Journal of Cleaner Production, 241, 118253-.	Modeling study only - no water quality data

https://doi.org/10.1016/j.jclepro.2019.118253	
PLUMBING: Rainwater harvesting. (2007). What's New in Building, 70-.	Not a research paper, no rainwater harvesting data
Preeti, P., & Rahman, A. (2021). A Case Study on Reliability, Water Demand and Economic Analysis of Rainwater Harvesting in Australian Capital Cities. Water (Basel), 13(19), 2606-. https://doi.org/10.3390/w13192606	Modeling study only - no water quality data
Professional Gardener - Draw future visitors. (2014). Horticulture Week, 24-.	Not a research paper, no rainwater harvesting data
Qin, Y. (2020). Urban Flooding Mitigation Techniques: A Systematic Review and Future Studies. Water (Basel), 12(12), 3579-. https://doi.org/10.3390/w12123579	review paper
Quaghebeur, W., Mulhern, R. E., Ronsse, S., Heylen, S., Blommaert, H., Potemans, S., Valdivia Mendizábal, C., & Terrazas García, J. (2019). Arsenic contamination in rainwater harvesting tanks around Lake Poopó in Oruro, Bolivia: An unrecognized health risk. The Science of the Total Environment, 688, 224–230. https://doi.org/10.1016/j.scitotenv.2019.06.126	Single sample location only from systems
Quintero Agudelo, A. C., Vargas Terranova, C. A., & Sanabria Alcantar, J. P. (2018). Evaluación de un sistema de fotocatálisis heterogénea y pasteurización para desinfección de aguas lluvias. Ciencia e Ingeniería Neogranadina, 28(1), 117–134. https://doi.org/10.18359/rcin.2350	Studied post-tank treatment only
Quon, H., Allaire, M., & Jiang, S. C. (2021). Assessing the Risk of Legionella Infection through Showering with Untreated Rain Cistern Water in a Tropical Environment. Water (Basel), 13(7), 889-. https://doi.org/10.3390/w13070889	Single samples only from systems
Rao, N. S., Dinakar, A., Sravanthi, M., & Kumari, B. K. (2021). Geochemical characteristics and quality of groundwater evaluation for drinking, irrigation, and industrial purposes from a part of hard rock aquifer of South India. Environmental Science and Pollution Research International, 28(24), 31941–31961. https://doi.org/10.1007/s11356-021-12404-z	Groundwater study

Rattenbury, J. M. (2012). Cistern filtration for rainwater harvesting. PM Engineer, 18(3), 29-.	No water quality data
Rattenbury, J. M. (2012). Cistern management for rainwater harvesting. PM Engineer, 18(6), 16-.	No water quality data
Rattenbury, J. M. (2012). Rainwater harvesting 101. PM Engineer, 18(1), 18-.	No water quality data
Rawan, B., Ullah, W., Ullah, R., Akbar, T. A., Ayaz, Z., Javed, M. F., Din, I., Ullah, S., Aziz, M., Mohamed, A., Khan, N. A., & Khan, O. (2022). Assessments of Roof-Harvested Rainwater in Disctrict Dir Lower, Khyber Pakhtunkhwa Pakistan. Water (Basel), 14(20), 3270-. https://doi.org/10.3390/w14203270	Samples only taken from the tank -- also, only physicochemical data
Rawan, B., Ullah, W., Ullah, R., Akbar, T. A., Ayaz, Z., Javed, M. F., Din, I., Ullah, S., Aziz, M., Mohamed, A., Khan, N. A., & Khan, O. (2022). Assessments of Roof-Harvested Rainwater in Disctrict Dir Lower, Khyber Pakhtunkhwa Pakistan. Water (Basel), 14(20), 3270-. https://doi.org/10.3390/w14203270	Single sample location only from systems
Reyneke, B., Ndlovu, T., Vincent, M. B., Martínez-García, A., Polo-López, M. I., Fernández-Ibáñez, P., Ferrero, G., Khan, S., McGuigan, K. G., & Khan, W. (2020). Validation of large-volume batch solar reactors for the treatment of rainwater in field trials in sub-Saharan Africa. The Science of the Total Environment, 717, 137223–137223. https://doi.org/10.1016/j.scitotenv.2020.137223	Tested a post-tank solar reactor treatment system
Rezende, J. H., & Tecedor, N. (2017). Aproveitamento de água de chuva de cobertura em edificações: dimensionamento do reservatório pelos métodos descritos na NBR 15527. Revista Ambiente & Água, 12(6), 1040–1053. https://doi.org/10.4136/ambi-agua.1940	No water quality data- focused on volume only
Richiardi, L., Pignata, C., Fea, E., Bonetta, S., & Carraro, E. (2023). Are Indicator Microorganisms Predictive of Pathogens in Water? Water (Basel), 15(16), 2964-. https://doi.org/10.3390/w15162964	Not about rainwater harvesting
Sabogal-Paz, L. P., Campos, L. C., Bogush, A., & Canales, M. (2020). Household slow sand filters in intermittent and continuous flows to treat water containing low mineral ion concentrations and Bisphenol A. The Science of the Total Environment, 702, 135078–135078. https://doi.org/10.1016/j.scitotenv.2019.135078	No rainwater quality data -- studied pilot slow sand filters

Sales-Ortells, H., & Medema, G. (2015). Microbial health risks associated with exposure to stormwater in a water plaza. Water Research (Oxford), 74, 34–46. https://doi.org/10.1016/j.watres.2015.01.044	About road runoff, not roofs
Sánchez, A. S., Cohim, E., & Kalid, R. A. (2015). A review on physicochemical and microbiological contamination of roof-harvested rainwater in urban areas. Sustainability of Water Quality and Ecology, 6, 119–137. https://doi.org/10.1016/j.swaqe.2015.04.002	Review paper
Scaramboni, C., Urban, R. C., Lima-Souza, M., Nogueira, R. F. P., Cardoso, A. A., Allen, A. G., & Campos, M. L. A. M. (2015). Total sugars in atmospheric aerosols: An alternative tracer for biomass burning. Atmospheric Environment (1994), 100, 185–192. https://doi.org/10.1016/j.atmosenv.2014.11.003	Not about rainwater harvesting
Schang, C., Schmidt, J., Gao, L., Bergmann, D., McCormack, T., Henry, R., & McCarthy, D. (2021). Rainwater for residential hot water supply: Managing microbial risks. The Science of the Total Environment, 782, 146889-. https://doi.org/10.1016/j.scitotenv.2021.146889	Pilot scale assessment of post-tank treatment only
Segal, A., Khanjar, N., Yang, J., Brooks, K., Williams, M., Little, N., Lazar, A., & Goldstein, R. E. R. (2024). Urban agriculture in Baltimore, Maryland: Documenting current irrigation practices and rainwater harvesting. Urban Agriculture & Regional Food Systems, 9(1). https://doi.org/10.1002/uar2.20075	No water quality data
Senevirathna, S., Ramzan, S., & Morgan, J. (2019). A sustainable and fully automated process to treat stored rainwater to meet drinking water quality guidelines. Process Safety and Environmental Protection, 130, 190–196. https://doi.org/10.1016/j.psep.2019.08.005	Only studied post-tank treatment- actually called stored rainwater raw water
Shammi, M., Rahman, M. M., Bondad, S. E., & Bodrud-Doza, M. (2019). Impacts of Salinity Intrusion in Community Health: A Review of Experiences on Drinking Water Sodium from Coastal Areas of Bangladesh. Healthcare (Basel), 7(1), 50-. https://doi.org/10.3390/healthcare7010050	Review of water quality data only

Silva, G. N. da, Alves, L. D., Santos, I. E. dos, Bila, D. M., Ohnuma Júnior, A. A., & Corrêa, S. M. (2020). An assessment of atmospheric deposition of metals and the physico -chemical parameters of a rainwater harvesting system in Rio de Janeiro Brazil, by means of statistical multivariate analysis. Revista Ambiente & Água, 15(4), 1–31. https://doi.org/10.4136/ambi-agua.2522	physicochemical quality only
Silveira, A., de Lima, J. L. M. P., Abrantes, J. R. C. B., & Mujtaba, B. (2017). Washout of Fine Sand Particles From a Ceramic Tile Roof: Laboratory Experiments Under Simulated Rainfall. Water, Air, and Soil Pollution, 228(9), 1-. https://doi.org/10.1007/s11270-017-3529-8	No microbial water quality data
Singh, S. K., Taylor, R. W., & Su, H. (2017). Developing sustainable models of arsenic-mitigation technologies in the Middle-Ganga Plain in India. Current Science (Bangalore), 113(1), 80–93. https://doi.org/10.18520/cs/v113/i01/80-93	No water quality data - survey only
Slys, D., & Stec, A. (2015). The Analysis of Variants of Water Supply Systems in Multi-Family Residential Building. Ecological Chemistry and Engineering. S, 21(4), 623-. https://doi.org/10.1515/eces-2014-0045	Computational only - no sampling
Soni, P., Dashora, Y., Maheshwari, B., Dillon, P., Singh, P., & Kumar, A. (2020). Managed Aquifer Recharge at a Farm Level: Evaluating the Performance of Direct Well Recharge Structures. Water (Basel), 12(4), 1069-. https://doi.org/10.3390/w12041069	Samples from wells -- though some are fed by rainwater
Stranzl, J. (2005). Mahlum Architects' design proposes greenest building in Olympia School District. Daily Journal of Commerce, 1-.	No water quality data
Sudiajeng, L., Wiraga, I. W., Parwita, I. G. L. M., & Budiadi, I. M. (2020). The effectiveness of horizontal water filtering system on deep rainwater harvesting wells. Journal of Physics. Conference Series, 1450(1), 12029-. https://doi.org/10.1088/1742-6596/1450/1/012029	This paper is examining groundwater recharge from collected rainwater
Technical Brief No11/Rainwater Harvesting. (1987). Waterlines, 5(3), 15–18.	Not a research paper, no rainwater harvesting data
Van Giesen, G. E. (2015). Harvesting rainwater. Plumbing & Mechanical, 33(9), 70–72.	No water quality data, not peer reviewed
Vashisht, A. K., & Aggarwal, R. (2016). Performance of cotton mat as pre-filtration unit for groundwater recharging. Current Science (Bangalore), 111(10), 1591–1595.	Not rainwater harvesting - studied a cotton mat filter with synthetic turbid water

Velumani, P., Mukilan, K., & Manikanda Prabhu, P. (2020). Long term preservation of rainwater for the exploitation of potable water. IOP Conference Series. Materials Science and Engineering, 872(1), 12116-. https://doi.org/10.1088/1757-899X/872/1/012116	Conference paper and unable to calculate log reductions from the data
Velumani, P., Mukilan, K., & Manikanda Prabhu, P. (2020). Long term preservation of rainwater for the exploitation of potable water. IOP Conference Series. Materials Science and Engineering, 872(1), 12116-. https://doi.org/10.1088/1757-899X/872/1/012116	Conference paper
Vianello, M., Vischetti, C., Scarponi, L., & Zanin, G. (2005). Herbicide losses in runoff events from a field with a low slope: Role of a vegetative filter strip. Chemosphere (Oxford), 61(5), 717–725. https://doi.org/10.1016/j.chemosphere.2005.03.043	Not about rainwater harvesting
Wang, W. P., Zhou, Y. Q., & Deng, H. Y. (2012). Pre-Treatment of Karst Groundwater Recharge with Roofwater System. Applied Mechanics and Materials, 212–213, 307-. https://doi.org/10.4028/www.scientific.net/AMM.212-213.307	Used zeolite filter and only looked at ammonia removal
Wang, Z., Qi, F., Liu, L., Chen, M., Sun, D., & Nan, J. (2021). How do urban rainfall-runoff pollution control technologies develop in China? A systematic review based on bibliometric analysis and literature summary. The Science of the Total Environment, 789, 148045–148045. https://doi.org/10.1016/j.scitotenv.2021.148045	Review paper
Waseem, M., Mutahir Ullah Ghazi, S., Ahmed, N., Ayaan, M., & Kebede Leta, M. (2023). Rainwater Harvesting as Sustainable Solution to Cope with Drinking Water Scarcity and Urban Flooding: A Case Study of Public Institutions in Lahore, Pakistan. CivilEng, 4(2), 638–656. https://doi.org/10.3390/civileng4020037	No water quality data
Wells, S., & Ervin, D. E. (2007). Academia embraces Green. Campus Facility Maintenance, 4(3), 28-.	No water quality data
Wilbers, G.-J., Sebesvari, Z., & Renaud, F. G. (2014). Piped-Water Supplies in Rural Areas of the Mekong Delta, Vietnam: Water Quality and Household Perceptions. Water (Basel), 6(8), 2175–2194. https://doi.org/10.3390/w6082175	No rainwater harvesting quality data
Yin, H.-B., & Patel, J. (2018). Comparison of methods to determine the microbial quality of alternative irrigation waters. Agricultural Water Management, 201, 38–45. https://doi.org/10.1016/j.agwat.2018.01.012	Data only at one point from RWH systems

Zdeb, M., Zamorska, J., Papciak, D., & Słyś, D. (2020). The Quality of Rainwater Collected from Roofs and the Possibility of Its Economic Use. Resources (Basel), 9(2), 12-. https://doi.org/10.3390/resources9020012	roof runoff - not rainwater harvesting
Zhao, X., Feng, J., Xiao, M., Shen, D., Tan, C., Song, X., Feng, J., Duley, W. W., & Zhou, Y. N. (2021). A Simple High Power, Fast Response Streaming Potential/Current-Based Electric Nanogenerator Using a Layer of Al2O3 Nanoparticles. ACS applied materials & interfaces, 13(23), 27169–27178. https://doi.org/10.1021/acsami.1c04290	Not about rainwater harvesting
Zhao, Y., Wang, X., Liu, C., Wang, S., Wang, X., Hou, H., Wang, J., & Li, H. (2019). Purification of harvested rainwater using slow sand filters with low-cost materials: Bacterial community structure and purifying effect. The Science of the Total Environment, 674, 344–354. https://doi.org/10.1016/j.scitotenv.2019.03.474	Filtration using slow sand filter as post-tank treatment
Zheng, L., & Deng, Y. (2024). Advancing rainwater treatment technologies for irrigation of urban agriculture: A pathway toward innovation. The Science of the Total Environment, 916, 170087–170087. https://doi.org/10.1016/j.scitotenv.2024.170087	Review paper
Zhu, K., Zhang, L., Hart, W., Liu, M., & Chen, H. (2004). Quality issues in harvested rainwater in arid and semi-arid Loess Plateau of northern China. Journal of Arid Environments, 57(4), 487–505. https://doi.org/10.1016/S0140-1963(03)00118-6	Single sample location only from systems

APPENDIX K

POTABLE RAINWATER CATCHMENT SYSTEMS

K 101.0 General.

K 101.1 Applicability. The provisions of this appendix shall apply to the installation, construction, alteration, and repair of potable rainwater catchment systems.

K 101.2 System Design. Potable rainwater catchment systems in accordance with this appendix shall be designed by a registered design professional or person deemed competent by the Authority Having Jurisdiction to perform potable rainwater catchment system design work.

K 101.3 Permit. It shall be unlawful for a person to construct, install, or alter, or cause to be constructed, installed, or altered a potable rainwater catchment systems in a building or on a premise without first obtaining a permit to do such work from the Authority Having Jurisdiction.

K 101.3.1 Plumbing Plan Submission. No permit for a rainwater catchment system requiring a permit shall be issued until complete plumbing plans, with data satisfactory to the Authority Having Jurisdiction, have been submitted and approved. No changes or connections shall be made to either the rainfall catchment or the potable water system within a site containing a rainwater catchment water system without approval by the Authority Having Jurisdiction.

K 101.3.2 System Changes. No changes or connections shall be made to either the rainwater catchment system or the potable water system within a site containing a rainwater catchment system requiring a permit without approval by the Authority Having Jurisdiction.

K 101.4 Product and Material Approval. System components shall be properly identified as to the manufacturer.

K 101.4.1 Plumbing Materials and Systems. Pipe, pipe fittings, traps, fixtures, material, and devices used in a potable rainwater system shall be listed or labeled (third-party certified) by a listing agency (accredited conformity assessment body) and shall be in accordance with approved applicable recognized standards referenced within this code, and shall be free from defects. Unless otherwise provided for in this appendix, materials, fixtures, or devices used or entering into the construction of plumbing systems, or parts thereof shall be submitted to the Authority Having Jurisdiction for approval.

K 101.5 Maintenance and Inspection. Potable rainwater catchment systems and components shall be inspected and maintained in accordance with Section K 101.5.1 through Section K 101.5.3.

K 101.5.1 Frequency. Potable rainwater catchment systems and components shall be inspected and maintained in accordance with Table K 101.5.1 unless more frequent inspection and maintenance are required by the manufacturer.

K 101.5.2 Maintenance Log. A maintenance log for potable rainwater catchment systems shall be maintained by the property owner and be available for inspection. The property owner or designated appointee shall ensure that a record of testing, inspection, and maintenance in accordance with Table K 101.5.1 is maintained in the log. The log will indicate the frequency of inspection, and maintenance of each system. A record of the required water quality tests shall be retained for not less than 2 years.

K 101.5.3 Maintenance Responsibility. The required maintenance and inspection of potable rainwater catchment systems shall be the responsibility of the property owner unless otherwise required by the Authority Having Jurisdiction.

K 101.6 Operation and Maintenance Manual. An operation and maintenance manual for potable rainwater catchment systems shall be supplied to the building owner by the system designer. The operating and maintenance manual shall include the following:

(1) Detailed diagram of the entire system and the location of system components.

(2) Instructions for operating and maintaining the system.

(3) Details on maintaining the required water quality as determined by the Authority Having Jurisdiction.

(4) Details on deactivating the system for maintenance, repair, or other purposes.

(5) Applicable testing, inspection, and maintenance frequencies in accordance with Table K 101.5.1.

(6) A method of contacting the manufacturer(s).

K 101.7 Minimum Water Quality Requirements. The minimum water quality for potable rainwater catchment systems shall comply with the applicable water quality requirements as determined by the Authority Having Jurisdiction. In the absence of water quality requirements, the guidelines EPA/625/R-04/108 contains recommended water reuse guidelines to assist regulatory agencies develop, revise, or expand alternate water source water quality standards.

K 101.8 Material Compatibility. In addition to the requirements of this appendix, potable rainwater catchment systems shall be constructed of materials that are compatible with the type of pipe and fitting materials and water conditions in the system.

K 101.9 System Controls. Controls for pumps, valves, and other devices that contain mercury that come in contact with the water supply shall not be permitted.

K 102.0 Connection.

K 102.1 General. No water piping supplied by a potable rainwater catchment system shall be connected to a source of supply without the approval of the Authority Having Jurisdiction, Health Department, or other department having jurisdiction.

TABLE K 101.5.1
MINIMUM POTABLE RAINWATER CATCHMENT SYSTEM TESTING, INSPECTION, AND MAINTENANCE FREQUENCY

DESCRIPTION	MINIMUM FREQUENCY
Inspect and clean filters and screens, and replace (where necessary).	Every 3 months
Inspect and verify that disinfection, filters and water quality treatment devices and systems are operational. Perform water quality tests in accordance with the Authority Having Jurisdiction.	In accordance with the manufacturer's instructions, and the Authority Having Jurisdiction.
Perform applicable water quality tests to verify compliance with Section K 104.3.	Every 3 months
Perform a water quality test for E. Coli, Total Coliform, and Heterotrophic bacteria. For a system where 25 different people consume water from the system over a 60 day period, a water quality test for cryptosporidium shall be performed.	After initial installation and every 12 months thereafter, or as directed by the Authority Having Jurisdiction.
Inspect and clear debris from rainwater gutters, downspouts, and roof washers.	Every 6 months
Inspect and clear debris from the roof or other aboveground rainwater collection surface.	Every 6 months
Remove tree branches and vegetation overhanging roof or other aboveground rainwater collection surface.	As needed
Inspect pumps and verify operation.	After initial installation and every 12 months thereafter
Inspect valves and verify operation.	After initial installation and every 12 months thereafter
Inspect pressure tanks and verify operation.	After initial installation and every 12 months thereafter
Clear debris and inspect storage tanks, locking devices, and verify operation.	After initial installation and every 12 months thereafter
Inspect caution labels and marking.	After initial installation and every 12 months thereafter

K 102.2 Connections to Public or Private Potable Water Systems. Potable rainwater catchment systems shall have no direct connection to a public or private potable water supply or alternate water source system. Potable water from a public or private potable water system is permitted to be used as makeup water to the rainwater storage tank provided the public, or private potable water supply connection is protected by an air gap or reduced-pressure principle backflow preventer in accordance with this code.

K 102.3 Backflow Prevention. The potable rainwater catchment system shall be protected against backflow in accordance with this code.

K 103.0 Potable Rainfall Catchment System Materials.

K 103.1 Collections Surfaces. The collection surface for potable applications shall be constructed of a hard, impervious material and shall be approved for potable water use. Roof coatings, paints, and liners shall comply with NSF Protocol P151.

K 103.1.1 Prohibited. Roof paints and coatings with lead, chromium, or zinc shall not be permitted. Wood roofing material and lead flashing shall not be permitted.

K 103.2 Rainwater Catchment System Drainage Materials. Materials used in rainwater catchment drainage systems, including gutters, downspouts, conductors, and leaders shall be in accordance with the requirements of this code for storm drainage.

K 103.3 Storage Tanks. Rainwater storage shall comply with Section K 105.0.

K 103.4 Water Supply and Distribution Materials. Potable rainwater supply and distribution materials shall comply with the requirements of this code for potable water supply and distribution systems.

K 104.0 Design and Installation.

K 104.1 Collection Surfaces. Rainwater shall be collected from a roof or other cleanable aboveground surfaces specifically designed for rainwater catchment. A rainwater catchment system shall not collect rainwater from:

(1) Vehicular parking surfaces

(2) Surface water runoff

(3) Bodies of standing water

K 104.2 Prohibited Discharges. Overflows, condensate, and bleed-off pipes from roof-mounted equipment and appliances shall not discharge onto roof surfaces that are intended to collect rainwater.

K 104.3 Minimum Water Quality. Upon initial system startup, the quality of the water for the intended application shall be verified at the point(s) of use as determined by the Authority Having Jurisdiction in accordance with Section K 104.3.1 and Section K 104.3.2. Water quality maintenance shall be in accordance with Section K 104.3.3.

K 104.3.1 Private Potable Water System. In the absence of water quality requirements determined by the Authority Having Jurisdiction, the minimum water quality for a private potable water system at the point of use shall comply with Table K 104.3.1.

TABLE K 104.3.1
MINIMUM WATER QUALITY

Escherichia coli (fecal coliform)	Non-detectable
Protozoan Cysts	Non-detectable
Viruses	Non-detectable
Turbidity	<0.3 NTU

K 104.3.2 Public Use Occupancies. The minimum water quality for a potable water system for public use occupancies at the point of use and testing procedures shall comply with the Environmental Protection Agency (EPA) Safe Drinking Water Act for a public water system.

K 104.3.3 Maintenance. Normal system maintenance shall require system testing for Escherichia coli (fecal coliform) and turbidity every 3 months in accordance with Table K 104.3.3. Upon failure of the fecal coliform test, the system shall be re-commissioned involving cleaning, and retesting in accordance with Section K 104.3. Testing for viruses and cysts shall occur once after 3 months of initial operation and once every 12 months thereafter.

Exception: Upon failure of the virus or cyst test, the tests will be repeated every 3 months until the tests results are negative for two consecutive tests.

TABLE K 104.3.3
MINIMUM SYSTEM MAINTENANCE REQUIREMENTS

Escherichia coli (fecal coliform)	Non-detectable
Turbidity	<0.3 NTU

K 104.4 Water Quality Devices and Equipment. Devices and equipment used to treat rainwater to maintain the minimum water quality requirements determined by the Authority Having Jurisdiction shall be listed or labeled (third-party certified) by a listing agency (accredited conformity assessment body) and approved for the intended application.

K 104.4.1 Filtration Devices. Potable water filters shall comply with NSF 53 and shall be installed in accordance with the manufacturer's installation instructions.

K 104.4.2 Disinfection Devices. Chlorination, ozone, ultraviolet, or other disinfection methods approved by the Authority Having Jurisdiction, or the product is listed and certified according to a microbiological reduction performance standard for drinking water, shall be used to treat harvested rainwater to meet the required water quality permitted. The disinfection devices and systems shall be installed in accordance with the manufacturer's installation instructions and the conditions of listing. Disinfection devices and systems shall be located downstream of the storage tank.

K 104.4.3 Filtration and Disinfection Systems. Filtration and disinfection systems shall be located after the water storage tank. Where a chlorination system is installed, it shall be installed upstream of filtration systems. Where an ultraviolet disinfection system is installed, a filter not more than 5 microns (5 μm) shall be installed upstream of the disinfection system.

K 104.5 Overhanging Tree Branches and Vegetation. Tree branches and vegetation shall not be located over the roof or other aboveground rainwater collection surface. Where existing tree branch and vegetation growth extends over the rainwater collection surface, it shall be removed in accordance with Section K 101.5.

K 105.0 Rainwater Storage Tanks.

K 105.1 General. Rainwater storage tanks shall be installed in accordance with Section K 105.2 through Section K 105.10.

K 105.2 Construction. Rainwater storage tanks shall be constructed of solid, durable materials not subject to excessive corrosion or decay and shall be watertight. Storage tanks shall be approved by the Authority Having Jurisdiction for potable water applications, provided such tanks are in accordance with approved applicable standards.

K 105.3 Location. Rainwater storage tanks shall be permitted to be installed above or below grade.

K 105.3.1 Above Grade. Above grade, storage tanks shall be of an opaque material, approved for aboveground use in direct sunlight, or shall be shielded from direct sunlight. Tanks shall be installed in an accessible location to allow for inspection and cleaning. The tank shall be installed on a foundation or platform that is constructed to accommodate loads in accordance with the building code.

K 105.3.2 Below Grade. Rainwater storage tanks installed below grade shall be structurally designed to withstand anticipated earth or other loads. Holding tank covers shall be capable of supporting an earth load of not less than 300 pounds per square foot (lb/ft^2) (1465 kg/m^2) where the tank is designed for underground installation. Below grade rainwater tanks installed underground shall be provided with manholes. The manhole opening shall be not less than 20 inches (508 mm) in diameter and located not less than 4 inches (102 mm) above the surrounding grade. The surrounding grade shall be sloped away from the manhole. Underground tanks shall be ballasted, anchored, or otherwise secured, to prevent the tank from floating out of the ground where empty. The combined weight of the tank and hold down system shall meet or exceed the buoyancy force of the tank.

K 105.4 Drainage and Overflow. Rainwater storage tanks shall be provided with a means of draining and cleaning. The overflow drain shall not be equipped with a shutoff valve. The overflow outlet shall discharge in accordance with this code for storm drainage systems. Where discharging to the storm drainage system, the overflow drain shall be protected from backflow of the storm drainage system by a backwater valve or other approved method.

K 105.4.1 Overflow Outlet Size. The overflow outlet shall be sized to accommodate the flow of the rainwater entering the tank and not less than the aggregate cross-sectional area of the inflow pipes.

K 105.5 Animals and Insects. Rainwater tank openings to the atmosphere shall be protected to prevent the entrance of insects, birds, or rodents into the tank.

K 105.6 Human Access. Rainwater tank access openings exceeding 12 inches (305 mm) in diameter shall be secured to prevent tampering and unintended entry by either a lockable device or other approved method.

K 105.7 Exposure to Sunlight. Rainwater tank openings shall not be exposed to direct sunlight.

K 105.8 Inlets. A device or arrangement of fittings shall be installed at the inlet of the tank to prevent rainwater from disturbing sediment as it enters the tank.

K 105.9 Primary Tank Outlets. The primary tank outlet shall be located not less than 4 inches (102 mm) above the bottom of the tank, or shall be provided with a floating inlet to draw water from the cistern just below the water surface.

K 105.10 Storage Tank Venting. Where venting using drainage or overflow piping is not provided or is considered insufficient, a vent shall be installed on each tank. The vent shall extend from the top of the tank and terminate not less than 6 inches (152 mm) above grade and shall be not less than 1½ inches (40 mm) in diameter. The vent terminal shall be directed downward and covered with a ½ of an inch (2.4 mm) mesh screen to prevent the entry of vermin and insect.

K 105.11 Pumps. Pumps serving rainwater catchment systems shall be listed for potable water use. Pumps supplying water to water closets, urinals, and trap primers shall be capable of delivering not less than the minimum residual pressure required by the highest and most remote outlet served. Where the water pressure in the rainwater supply system within the building exceeds 80 psi (552 kPa), a pressure reducing valve reducing the pressure to 80 psi (552 kPa) or less to water outlets in the building shall be installed in accordance with this code.

K 105.12 Roof Drains. Primary and secondary roof drains, conductors, leaders, overflows, and gutters shall be designed and installed in accordance with this code.

K 106.0 Freeze Protection.

K 106.1 General. Tanks and piping installed in locations subject to freezing shall be provided with an approved means of freeze protection.

K 106.2 Roof Washer or Pre-Filtration System. Collected rainwater shall pass through a roof washer or pre-filtration system before the water enters the rainwater storage tank. Roof washer systems shall comply with Section K 106.2.1 through Section K 106.2.4.

K 106.2.1 Size. The roof washer shall be sized to direct rainwater containing debris that has accumulated on the collection surface away from the storage tank. ARCSA/ASPE 63 contains additional guidance on acceptable methods of sizing roof washers.

K 106.2.2 Debris Screen. The inlet to the roof washer shall be provided with a debris screen or other approved means that protects the roof washer from the intrusion of debris and vermin. Where the debris screen is installed, the debris screen shall be corrosion resistant and shall have openings not larger than ½ of an inch (12.7 mm).

K 106.2.3 Drain Discharge. Water drained from the roof washer, or pre-filter shall be diverted away from the storage tank and discharged to a disposal area that does not cause property damage or erosion. Roof washer drainage shall not drain over a public way.

K 106.2.4 Automatic Drain. Roof washing systems shall be provided with an automatic means of self-draining between rain events.

K 106.3 Roof Gutters. Gutters shall maintain a minimum slope and be sized in accordance with this code.

K 106.4 Drains, Conductors, and Leaders. The design and size of rainwater drains, conductors, and leaders shall comply with this code.

K 106.5 Size of Potable Water Piping. Potable rainwater system distribution piping shall be sized in accordance with this code for sizing potable water piping.

K 107.0 Cleaning.

K 107.1 General. The interior surfaces of tanks and equipment shall be clean before they are put into service.

K 108.0 Supply System Inspection and Test.

K 108.1 General. Rainwater catchment systems shall be inspected and tested in accordance with the applicable provisions of this code for testing of potable water and storm drainage systems. Storage tanks shall be filled with water to the overflow opening for 24 hours, and during the inspection, or by other means as approved by the Authority Having Jurisdiction. Seams and joints shall be exposed during the inspection and checked for water tightness.