Water System Design Manual

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Washington State Department of
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Division of Environmental Health
Office of Drinking Water

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Water System Design Manual

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Acknowledgments

This is the third edition of the *Water System Design Manual*. The Department of Health prepared this document to provide guidelines and criteria for design engineers that prepare plans and specifications for Group A public water systems.

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Table of Contents

Table of Contents - Continued

Table of Contents - Continued

Table of Contents - Continued

Table of Contents - Continued

Abbreviations

AC	Authorized consumption
ADD	Average day demand
ANSI	American National Standards Institute
APWA	American Public Works Association
ASHRAE	American Society of Heating, Refrigeration, and Air Conditioning Engineers
ASCE	American Society of Civil Engineers
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing and Materials
AWWA	American Water Works Association
BPS	Booster pump station
CFR	Code of Federal Regulations
CRS	Capacity-related storage
CSV	Cycle stop valve
CT	Chlorine concentration x time
DBP	Disinfection byproduct
DE	Diatomaceous earth
DOH	Department of Health
DS	Dead storage
DSL	Distribution system leakage
DVGW	*Deutsche Vereinigung des Gas und Wasserfaches*
EDB	Ethylene Dibromide
EPA	Environmental Protection Agency
EPS	Extended-period simulation
ERU	Equivalent residential unit
ES	Equalizing storage
ETV	Environmental testing verification
fps	Feet per second
FSS	Fire suppression storage
GAC	Granular activated carbon

Abbreviations

gpd	Gallons per day
gpm	Gallons per minute
GW	Groundwater
GWI	Groundwater under the direct influence of surface water
HAA5	Haloacetic acids (five)
IESWTR	Interim Enhanced Surface Water Treatment Rule
IOC	Inorganic chemical
L&I	Department of Labor and Industries
LT1ESWTR	Long Term 1 Enhanced Surface Water Treatment Rule
LT2ESWTR	Long Term 2 Enhanced Surface Water Treatment Rule
MCL	Maximum contaminant level
MDD	Maximum day demand
MF	Multiplying factor
mg/L	Milligrams per liter
MMAD	Maximum month's average day demand
MPA	Microscopic particulate analysis
MPDES	National pollutant discharge elimination system
NPDES	National Primary Discharge Elimination System
NSF	NSF International (formerly National Sanitation Foundation)
NTU	Turbidity range
O&M	Operations and maintenance
ÖNORM	*Österreichisches Normungsinstitut*
OS	Operational storage
OSHA	Occupational Safety and Health Administration
PAC	Powdered activated carbon
PHD	Peak hourly demand
POE	Point-of-entry
POU	Point-of-use
PRV	Pressure reducing valve, Pressure relief valve
psi	Pounds per square inch

Abbreviations

psig	Pounds per square inch gauge
RCW	Revised Code of Washington
RED	Reduction equivalent dose
RO	Reverse osmosis
RPBA	Reduced-pressure backflow assembly
RSSCT	Rapid small-scale column test
SB	Standby storage
SCA	Sanitary control area
SCADA	Supervisory Control and Data Acquisition
SEPA	State Environmental Policy Act
SOC	Synthetic organic chemical
SMACNA	Sheet Metal and Air Conditioning Contractors National Association
SW	Surface water
SWSMP	Small water system management program
TDS	Total dissolved solids
TOC	Total organic carbon
TP	Total water produced and purchased
TS	Total storage
TTHM	Total trihalomethane
UPC	Uniform Plumbing Code
USC	University of Southern California
UV	Ultraviolet
UVDGM	Ultraviolet Disinfection Guidance Manual
VOC	Volatile organic chemical
WAC	Washington Administrative Code
WHPA	Wellhead protection area
WISHA	Washington Industrial Safety and Health Act
WSDM	Water System Design Manual
WSDOE	Washington State Department of Ecology
WSDOT	Washington State Department of Transportation

Abbreviations

WSDSHS	Washington State Department of Social and Health Services
WSP	Water system plan
WUE	Water use efficiency
USEPA	U.S. Environmental Protection Agency

Regulatory Citations

Citation	Title
Chapter 18.43 RCW	Engineers and land surveyors
Chapter 49.17 RCW	Washington industrial safety and health act
Chapter 70.116 RCW	Public water system coordination act of 1977
Chapter 70.79 RCW	Boilers and unfired pressure vessels
Chapter 90.03.383 RCW	Interties – Findings – Definitions – Review and approval
Chapter 90.44 RCW	Regulation of public groundwaters
Chapter 173-160 WAC	Minimum standards for construction and maintenance of wells (Department of Ecology)
Chapter 173-303 WAC	Dangerous waste regulations (Department of Ecology)
Chapter 246-03 WAC	State environmental policy act – guidelines (Department of Health)
Chapter 246-10 WAC	Administrative procedure – adjudicative proceedings (Department of Health)
Chapter 246-290 WAC	Group A public water supplies (Department of Health)
Chapter 246-292 WAC	Water works operator certification (Department of Health)
Chapter 246-293 WAC	Water system coordination act (Department of Health)
Chapter 246-294 WAC	Drinking water operating permits (Department of Health)
Chapter 246-295 WAC	Satellite system management agencies (Department of Health)
Chapter 296-24 WAC	General safety and health standards (Department of Labor and Industries)
Chapter 296-62 WAC	General occupational health standards (Department of Labor and Industries)
Chapter 296-65 WAC	Asbestos removal and encapsulation (Department of Labor and Industries)
Chapter 296-104 WAC	Board of boiler rules – substantive (Department of Labor and Industries)
Chapter 296-155 WAC	Safety standards for construction work (Department of Labor and Industries)
Chapter 296-876 WAC	Ladders, portable and fixed (Department of Labor and Industries)

Preface

This edition of the *Water System Design Manual* is for water system design in Washington, especially for small water systems serving fewer than 500 residential connections. However, the Department of Health (DOH) recognizes that existing local ordinances, consumer service expectations, and existing water use data often provide more appropriate design criteria. DOH advocates the use of water system specific information, especially accurate meter records, for existing water system expansions.

DOH's approach in creating this edition of the manual involved:

- Developing performance standards rather than prescriptive standards.
- Placing mandatory requirements in WAC with corresponding references to support "shall" or "must" statements in the *Water System Design Manual*.
- Providing alternative design approaches when a specific proposal meets "good engineering practice" and is supported by documented justification.
- Allowing individual water system customers to participate in determining their own level or standard of reliable water service under abnormal circumstances, as long as public health protection is not compromised.
- Establishing a basic "standard of care" for engineering professionals involved in water system design.
- Explaining new design elements and clarifying or updating elements that seemed confusing in previous editions.

Water System Reliability Considerations
"All public water systems shall provide an adequate quantity and quality of water in a reliable manner at all times consistent with the requirements of this chapter" (WAC 246-290-420). "Reliability" applies to expectations consumers may have in obtaining sufficient water, at an acceptable pressure.

Therefore, reliability often differs based on customer viewpoints about an appropriate level of service. Consumers expect their water pressure to be adequate for routine uses. From a public health perspective, low pressure creates opportunities for backflow or seepage that could allow contaminants to enter drinking water. High pressure may lead to excessive leakage or failure of system facilities.

State public drinking water system rules largely focus on safety and reliability. A reliable water system is designed and then operated to meet the needs and expectations of consumers at all times. The two elements affecting the adequacy of a water system's reliability are:

- Source reliability
- Facility reliability

Source Reliability

Source reliability depends on the availability of water to meet consumer demands in a given period. Under drought conditions, line breaks, unscheduled power outages, or other unusual circumstances, water systems may need to limit consumer water use. Consumer acceptance of the extent of the limitation during such periods can be expected to vary.

Surface water reliability is dependent on rainfall, snow pack, and runoff rates, especially during extended drought. Reliability depends on how frequently a water system expects water availability to be limited. This is expressed as the one-in-10, -20, -50, or even -100 year recurrence intervals for water limitations.

It is important for water systems that depend on surface water to let consumers know of the potential limitations. For example, consumers should know that water may not always be present in unrestricted quantities. If a water system adopts a standard of 98 percent reliability, consumers should expect restrictions on water use at least once every 50 years. A lower standard would suggest a more frequent curtailment. In this context, reliability becomes a balance between consumer expectations and the cost of achieving such expectations.

Climatic changes also affect groundwater source reliability. However, the effect may not be as rapid or as great. Groundwater source reliability relates more to the estimated sustainable yield of an aquifer. Engineers use pumping tests and hydrogeological analyses to determine the sustainable yield of an aquifer. The extent of the analysis usually relates to the size of the utility and its willingness to expend resources to gain the necessary data. Chapter 7 outlines pumping test procedures for wells.

Facility Reliability

Facility reliability depends on the ability of water system facilities, such as pumps, storage tanks, and pipelines, to deliver adequate quantities of water over specified timeframes. The frequency and duration of service interruptions, and the cost required to minimize them, affect consumer expectations. Consumer expectations often drive decisions on improvements that provide higher levels of reliability for a water system.

Consumers may accept service interruptions for one, maybe two, days a year because of water system flushing, cleaning, maintenance or repair. However, they may not accept water outages for three or four hours each month, or at any time for more than two consecutive days. The water system should consider events limiting to water availability, and weigh the higher cost (engineering and construction) of gaining added reliability against the costs associated with interruptions of service.

Increasing Reliability

Multiple sources of supply provide increased reliability. The water system can still provide some service if a source fails or is taken off line. Different power grids can serve multiple sources making the water system less vulnerable to disruption due to localized power outages.

Recognizing the constraints on the availability of additional water resources and associated water rights, DOH advises engineers against designs based on 24-hours per day pumping to meet peak day demands. Having a total source capacity of 120 to 130 percent of projected peak day demand provides an increased ability to meet unexpected demands.

Multiple pumps in a well provide more reliability than a single pump (if one pump fails, the water system can still provide water). The water system could limit or discontinue water production for a designated period while the failed pump is pulled for repair or replacement. If consumers are informed in advance of the scheduled water restriction, they may not consider it unreasonable, or a reliability concern.

Gravity storage tanks allow water systems to deliver water, including fire flow, when they have neither power nor additional water sources available. Water systems with multiple gravity storage tanks can take one tank out of service for inspection, cleaning, or repair without interrupting consumer service.

A community should consider whether its sewer system relies on power for pumping. If it does, it may not function during a power outage. Providing water service under this situation may result in sanitary sewer backups or overflows increasing the risk to public health. If a water system can deliver water during a power outage, the community should also provide for wastewater collection and pumping under those circumstances.

If gravity storage is not feasible due to topography, the purveyor should evaluate elevated storage before deciding on ground level storage with booster pumping facilities. DOH recommends having standby power available when relying on pumps to deliver water and maintain water system pressure. An on-site generator that starts automatically when power supply is interrupted is best, especially if fire flow relies on existing pumps. A purveyor may choose to use a portable generator that can be moved from site to site. In this case, it is beneficial to have the connection and transfer switch established in advance so that it is quick and easy to use the portable generator. Reliable power to the site may also be provided by the power supplier through multiple primary leads from separate substations.

Chapter 5 has a summary of DOH recommendations on general water system reliability. Recommendations on specific water system components are in the chapters that address those components.

Reliability is also considered with longer-range planning activities for a water system. Plans to ensure long-range water system reliability should address:

- Water shortage response activities.
- Long-term adequacy of water rights for meeting growth expectations of the water system.
- Conservation as a mitigating practice to reduce the frequency or degree of curtailment when water availability is marginal.

See the *DOH Water System Planning Handbook* (DOH 331-068) for further information and detail regarding these concepts for longer-range system reliability.

Chapter 1: Introduction

This chapter outlines the purpose and scope of the *Water System Design Manual*. It also addresses the interrelationship of various design criteria with state and local rules, or other design criteria.

If you have questions about this manual or the requirements in chapter 246-290 WAC, Group A Public Water Supplies, contact one of the Department of Health (DOH) regional offices listed in Table 1-1.

1.0 Purpose and Scope

This manual provides guidelines and criteria for design engineers to use for preparing plans and specifications for Group A water systems to comply with the Group A Public Water Supplies (chapter 246-290 WAC). Group A water systems typically serves drinking water to 15 or more connections. This manual also clarifies the engineering document submittal and review requirements.

DOH staff based this manual on standard engineering practice and proven technology for treatment applications. We attempted to integrate a design philosophy that allows engineers some flexibility for the design of water systems. We encourage design engineers to consider various alternatives and options before selecting the overall optimum design for the situation.

We developed the manual to help:

- Establish, as far as practical, uniform concepts for water system designs.
- DOH regional engineers apply consistent review procedures.

Separate DOH guidance is available for Group B water systems. However, engineers should use this manual if the design guidance for Group B water systems is not sufficiently extensive or appropriate. This could occur, for example, when a Group B water system design involves complex treatment, standby storage, or fire flow.

1.1 Applicability

The criteria in this manual apply to:

- All new Group A water systems.
- New pressure zones within existing Group A water systems.
- Replacements or additions to distribution facilities within existing pressure zones of Group A water systems.

Although many water systems were built before the rule established minimum design and operating pressure requirements (chapter 246-290 WAC), engineers should use the most recent standards and guidelines when designing new facilities or additions. Designs should accommodate the new standards or criteria whenever infrastructure replacement is under consideration.

Design engineers may use design approaches other than those in this manual as long as they do not conflict with chapter 246-290 WAC. DOH will expect the design engineer to justify the alternate approach used and the criteria that apply.

1.2 "Must" versus "Should"

Throughout this manual we use "**must**," "**will**," "**shall,**" or "**required**" when design practice is sufficiently standardized to permit specific delineation of requirements, or where safeguarding the public health justifies definitive criteria or action (such as state statute or rule requirements). "Should" or "recommend," indicate procedures, criteria, or methods that are not required and that can be approached with some degree of flexibility. Engineers need to explain the basis of the altered approach or, in specific circumstances, why another approach may be more applicable.

1.3 Relationship with Planning Requirements

The purpose of a water system plan (WSP) or a small water system management program (SWSMP) is to provide a uniform process for water systems to:

1. Identify present and future needs.
2. Set forth means for addressing those needs.
3. Prove the water system has the operational, technical, managerial, and financial capability to achieve and maintain compliance with all relevant local, state, and federal plans and rules.
4. Demonstrate that the water system's physical capacity and water rights are sufficient for current and future needs.
5. Document water use efficiency measures (see WAC 246-290-800).

You should reference information in a WSP or SWSMP when proposing new facilities or modifications to existing facilities.

1.3.1 Planning Requirement

The following categories of Group A community water systems (see WAC 246-290-100) **must** prepare a WSP for DOH review and approval:

1. Water systems with 1,000 or more services.
2. Water systems required to develop WSPs under the Public Water System Coordination Act (chapter 70.116 RCW).

3. Water systems experiencing problems related to planning, operation, or management as determined by DOH.
4. New community water systems.
5. Expanding water systems.
6. Water systems proposing to use the "document submittal exception process" (see WAC 246-290-125).

Any noncommunity, nontransient, and community water system not required to complete a WSP **must** prepare a small water system management program as described in WAC 246-290-105.

1.3.2 Capital Improvement Plan

Ideally, all water systems required to complete a WSP would identify all future projects in the capital improvement program portion of a WSP. However, DOH recognizes that it is impractical over the six-year life of the plan to identify every possible project, such as some small water line replacements, that a water system may need. Therefore:

1. All anticipated projects should be identified in the WSP.
2. Distribution mains not in a WSP may be built without amending the WSP if construction follows standard specifications included in a current DOH-approved WSP, and the area to be served is addressed in the scope of the approved plan.
3. Other distribution system projects (such as storage facilities and booster pump stations) and non-distribution projects (such as source of supply and water quality treatment) **must** be included in a DOH-approved WSP prior to their construction, unless otherwise specifically authorized by DOH (see WAC 246-290-110(3) and 120(3)). DOH usually requires an amendment to the WSP if such a project is not already in the WSP. In some cases, a project report may be sufficient. Check with DOH regional office staff if you are uncertain (see Table 1-1).

Note: *See Chapter 4 for capital improvement program requirements related to submittal exceptions.*

1.4 Engineering Requirements

Water systems **must** be designed by professional engineers who are licensed (see chapter 18.43 RCW) in Washington State and who are qualified and experienced in designing drinking water systems and their various components (WAC 246-290-040).

Note: *A 1993 court decision provides direction to the Board of Licensing and DOH. It says "Non-professional engineer designers (including laypersons and registered sanitarians) will not be permitted or authorized to design water systems except those serving fewer than 10 connections, consisting solely of a simple well and pressure tank with one pressure zone and not providing any special treatment or having special hydraulic considerations."*

1.5 General Engineering Project Submittal Requirements

All engineering project reports and construction documents submitted to DOH should be complete. DOH will not correct or complete the submittals. Failure to comply with any minimum requirements could result in the project submittal being returned. Incomplete project submittals will result in delayed project review because it takes time to request and then receive the missing information.

1.6 Minimum System Design Requirements

Good engineering practice (as determined by the Washington State Professional Licensing Board) **must** be used in all aspects of water system design (WAC 246-290-200). The design engineer **must** consider the water system operation under a full range of expected demands (minimum to maximum) and emergency conditions (WAC 246-290-200). “Emergency” means a natural or man-made event that causes damage or disrupts normal operations and requires prompt action to protect public health and safety. Examples include fires, power outages, water-main breaks, water system component or treatment process failures, or recent evidence of contaminated drinking water.

1.7 Sizing Criteria and Water Rights

DOH developed this manual to help ensure that public health is not jeopardized by insufficient facility sizing, water quality problems, or reliability issues. Facilities should be sufficient to meet all customers’ water demands during peak day or peak hour operating conditions (when water use is at its highest).

Department of Ecology does not always base its water allocation and permitting decisions on DOH design standards or criteria. On a per household basis, this could result in a comparatively reduced water allocation (water right), due to water resource constraints within a watershed or groundwater basin.

Send questions about water rights to:

Department of Ecology
Water Resources Section
PO Box 47600
Olympia, WA 98504-7600
Phone: (360) 407-6000

Additional information on water rights is in Chapters 4, 5, and 7.

1.8 Department of Health Policies, Procedures, and Guidelines

Appendix A explains how to get the most recent DOH policies, guidelines, and procedures. See Appendix B for copies of three DOH guidance documents routinely used for water works design needs. Contact your DOH regional office (see Table 1-1) for clarification or more recent copies of DOH policies, procedures and guidelines. Unless noted otherwise, you may consider all procedures or guidelines referenced in this manual to be DOH's recommendation leading to compliance with the standards set forth in chapter 246-290 WAC.

1.9 Ten State Standards

The latest edition of *Recommended Standards for Water Works* (commonly called the Ten State Standards) (Ten State Standards 2007) contains acceptable guidelines for good engineering practice (WAC 246-290-200). However, DOH prefers the criteria specified in this manual when it differs from the criteria in the Recommended Standards for Water Works.

You may order copies of the *Recommended Standards for Water Works* from:

Health Education Services
A Division of HRI
PO Box 7126
Albany, New York 12224
Phone: (518) 439-7286

1.10 State Environmental Policy Act Considerations

DOH must consider State Environmental Policy Act (SEPA) requirements when approving project or construction documents. Before construction, SEPA requires certain types of projects to have an environmental impact statement, a SEPA determination of non-significance, or a document explaining why SEPA does not apply to the project (chapter 246-03 WAC).

These requirements apply to:

- All surface water source development.
- All water system storage facilities greater than 0.5 million gallons.
- New transmission lines longer than 1,000 feet and more than 8 inches in diameter located in new right of ways.
- Major extensions to existing water distribution systems that will use pipes more than 8 inches in diameter and increase the existing service area by more than 1-square mile.
- WSPs for water systems serving 1,000 or more connections.

1.11 Other Referenced Documents and Standards

We cite other waterworks-related laws, guides, standards and other documents in this manual to provide appropriate references. These references form a part of this manual, but it is not our intent to duplicate them. If references are not available, this manual defines the appropriate design procedures.

If the information in this manual conflicts with any referenced material, this manual should take precedence for purposes of designing water system facilities to meet DOH requirements. Otherwise, the design engineer is responsible for adequately justifying deviation from these guidelines when submitting the project design to DOH for review and approval.

All water system designs **must** also comply with locally adopted national model codes such as the *International Building Code* and *Uniform Plumbing Code*, and conform to other applicable industry standards and guidance such as that from the American Water Works Association (AWWA), and the American Society of Civil Engineers (ASCE) (WAC 246-290-200).

See Appendix C for a list of professional organizations and agencies with established standards and criteria referenced within this manual or the regulations.

1.12 U.S. Environmental Protection Agency Policy for Submetered Properties

The rule identifies the conditions in which a water delivery water system is not considered a water system (WAC 246-290-020).

A water system is not subject to the state drinking water rule for Group A water systems if it meets all the following criteria:

1. It consists only of distribution or storage facilities without source or treatment facilities.
2. It obtains all its water from another regulated water system.
3. It is not an interstate passenger conveyance carrier.
4. It does not sell water directly to any person.

Historically, some multifamily developments or additions to existing water systems were considered separate regulated water systems because they did not meet all of the criteria. This was especially true for developments that sold water to their consumers. In 2003, an Environmental Protection Agency (EPA) policy clarified that apartment buildings and other properties with characteristics similar to apartment buildings are not considered water systems if they meter their tenants' water use.

State drinking water law no longer treats apartment owners who install meters (submeters) and bill their tenants for actual water consumption as water systems subject to full regulation. Because this change removed the regulatory burden for property owners who previously submetered and billed for water service, DOH expects it to encourage more tenant submetering (and better water use efficiency practice).

Design engineers should recognize this rule change and ensure that extensions or additions of water service by a water system to an apartment or other multifamily development are assessed properly. Although the water system may count the addition as one connection through a master meter, water demand will be much higher than a typical single-family connection. See Chapter 6 for more details on calculating the required service levels.

Note: *While DOH no longer considers submetered properties as candidates for regulation based solely on the "selling water" criteria, we do consider such property a "public water system" subject to corrective actions if a public health risk arises. We also consider each apartment in the complex or building to be an individual connection for documenting the number of connections served by a water system. See Chapter 6 for more details on the analyzing the physical capacity needed to serve such connections.*

References

Great Lakes-Upper Mississippi River Board of State and Provincial Public Health and Environmental Managers. 2007. *Ten State Standards - Recommended Standards for Water Works*. Health Education Service, Albany, NY.

Table 1-1: Office of Drinking Water Regional Offices

Eastern Region	Serving
Drinking Water Eastern Regional Office **16201 E. Indiana Ave., Suite 1500** **Spokane Valley, WA 99216** **Phone: (509) 329-2100** **Fax: (509) 329-2104** **TDD Relay: 1-800-833-6388**	Adams, Asotin, Benton, Chelan, Columbia, Douglas, Franklin, Ferry, Garfield, Grant, Kittitas, Klickitat, Lincoln, Okanogan, Pend Orielle, Spokane, Stevens, Walla Walla, Whitman, and Yakima counties
Northwest Region	**Serving**
Drinking Water Northwest Regional Office **20435 – 72nd Ave. South, Suite 200** **Kent, WA 98032** **Phone: (253) 395-6750** **Fax: (253) 395-6760** **TDD Relay: 1-800-833-6388**	Island, King, Pierce, San Juan, Skagit, Snohomish, and Whatcom counties
Southwest Region	**Serving**
Drinking Water Southwest Regional Office **Physical: 243 Israel Road** **Tumwater, WA 98501** **Mailing: PO Box 47823** **Olympia, WA 98504-7823** **Phone: (360) 236-3030** **Fax: (360) 664-8058** **TDD Relay: 1-800-833-6388**	Clallam, Clark, Cowlitz, Grays Harbor, Jefferson, Kitsap, Lewis, Mason, Pacific, Skamania, Thurston, and Wahkiakum counties

Regional engineer assignments are subject to change. Contact the appropriate regional office for the name of the engineer assigned to your county. Get this information online at **http://www.doh.wa.gov/ehp/dw/Staff_Lists/dwnames.htm**

Chapter 2: Project Reports

This chapter discusses the items engineers should include in their project reports. A project report describes the basis for a project and includes calculations to show how the project will meet its objectives (WAC 246-290-110). Engineers usually prepare the project report before the project construction documents (detailed design drawings and construction specifications). See Chapter 3 and WAC 246-290-120 for construction document requirements.

2.0 Relationship to Water System Plans

Often the information required in a project report is already in a water system plan (WSP). If so, instead of repeating it, you can reference the applicable sections of the WSP in the project report. See Section 1.3 for guidance on WSPs. WAC 246-290-100(3) allows you to combine project reports with a WSP. If sufficient justification and documentation is in the WSP, a separate project report may not be needed.

2.1 Submittal to the Department of Health for Review and Approval

DOH **must** approve a project report **prior to** construction of a water facility project (WAC 246-290-110(2)). Exceptions to this requirement are in WAC 246-290-125 and Section 4.4. All project reports **must** satisfy WAC 246-290-110. Project reports are subject to review by a professional engineer as part of the submittal exception process (WAC 246-290-125(3)(e)(vii) also see Section 4.5).

2.2 Project Report Contents

The following is a general outline of the items that, at a minimum, should be in all project reports. For specific project requirements, see the appropriate chapter of this manual or the applicable sections of chapter 246-290 WAC. For instance, all of WAC 246-290-130 is dedicated to source approval.

The level of detail in the project report should reflect the complexity of the project. In general, source approval and water quality treatment projects should be more detailed than other types of projects. Project reports **must** be consistent with WAC 246-290-200.

In Sections 2.2.1 through 2.2.9, items identified as mandatory are in WAC 246-290-110(4)(a) through (i).

2.2.1 Project Description

Provide the following by citing specific references in a WSP or, preferably, including a narrative discussion in the project report (WAC 246-290-110(4)). You **must** describe the project and include:

1. A description of the problem or problems being addressed and why the project is proposed.
2. A summary of the recommended alternative (if applicable per Section 2.2.3), proposed construction schedule, estimated project cost, and financing method.
3. The relationship of the project to other water system components.
4. A statement of change in the physical capacity of the water system and its ability to serve customers, if applicable.
5. A copy of the environmental impact statement or determination of non-significance, or explain why the State Environmental Policy Act (SEPA) does not apply to the project. See SEPA chapter 246-03 WAC.
6. Source development information, if applicable.
7. The type of treatment, if applicable.

2.2.2 Planning

If a purveyor must have a WSP, DOH will not consider a project report for approval unless the purveyor has a current, approved WSP on file with DOH (WAC 246-290-110(3)). If the approved WSP does not adequately address the project, a WSP amendment is required. If the water system does not have a WSP, DOH may enter into a compliance agreement granting the purveyor time to complete it.

If a WSP is not required by WAC 246-290-100, the project report **must** include the following planning-related information:

1. General project background, with population and water demand forecasts.
2. A service area map. Municipal water suppliers must identify their water rights place of use on this map.
3. A description of the project's affect on neighboring water systems.
4. Local requirements, such as rates and duration of fire flow.
5. Additional management responsibilities, such as those in WAC 246-290-105, 415, and chapter 246-292 WAC, Water Works Operator Certification. See also Section 2.2.9.
6. A project implementation and construction schedule, including project phasing, if applicable.
7. Estimated capital and operating costs, and financing method, if applicable.
8. A *Water Rights Self Assessment Form*, if it is applicable to the type of project proposed. This form is on the DOH Web site listed in Appendix A.

2.2.3 Analysis of Alternatives

A comparison of alternative solutions and the rationale for selecting a proposed alternative is **required** for all types of projects (WAC 246-290-110(4)(c)). If projects involve new sources or water treatment, the comparison should include life-cycle cost evaluations and account for initial costs as well as on-going operations and maintenance costs. If this analysis is part of a DOH-approved WSP, you may reference applicable sections of the plan.

2.2.4 Water Quality

The project report **must** include a review of water quality as it relates to the purpose of the proposed project, including results of raw- and finished-water quality analyses (WAC 246-290-110(4)(d)). If the project involves water treatment or a filtration pilot study, see Chapter 12 and applicable sections of chapter 246-290 WAC.

2.2.5 Water Quantity and Water Rights

The project report **must** address water rights if the project involves a new source or an increase in the water system's physical capacity (WAC 246-290-110(4)(e)). You can do so by completing a *Water Rights Self Assessment Form* and evaluating the source physical capacity. This form is on the DOH Web site (see Appendix A). **If the assessment is in an approved WSP, you do not have to repeat the information**.

2.2.6 Engineering Calculations

Describe how the project complies with design considerations in Section 2.2.7. The project report or DOH-approved WSP **must** include the physical capacity analysis, hydraulic analysis, and sizing justification (WAC 246-290-110(4)(f)). It must also include other relevant technical considerations necessary to support the project. For guidance on ways to analyze the physical capacity of a water system, see Chapter 6. For hydraulic analysis considerations, see Section 8.2.

2.2.7 Design Criteria

Engineers **must** include specific design criteria in the project report (WAC 246-290-110(g)). These criteria include:

1. Design and construction standards, including performance standards, construction materials and methods, and sizing criteria, as applicable.
2. Locally adopted design standards relevant to the project, including fire flow requirements.

Consult the appropriate chapters of this manual to determine whether any additional engineering and design information is required.

2.2.8 Legal Considerations

You **must** identify legal issues such as ownership, right-of-way, sanitary control area, and restrictive covenants (water-related restrictions recorded on titles or deeds), and relationships with the boundary review board or Washington Utilities and Transportation Commission in the project report (WAC 246-290-110(4)(i)). Boundary review boards exist in most Washington counties. They guide and control the growth of municipalities and special purpose districts.

Your project report should also identify and discuss any legal conditions or considerations associated with projects under the direction or management of a satellite management agency.

2.2.9 Operations and Maintenance Considerations

If the following elements are not in a DOH-approved WSP, include them in the project report for all projects that add considerably to the operational and maintenance needs of the water system (such as storage tanks, booster pump facilities, source of supply, and water quality treatment):

1. Describe the routine operations tasks and frequencies.
2. Describe the preventive maintenance tasks and frequencies.
3. Discuss the estimated operations and maintenance costs related to the project.
4. Explain whether the project requires a certified operator (chapter 246-292 WAC) or a satellite system manager (chapter 246-295 WAC).

If none of these items are in a current WSP, the next WSP update **must** address the new project's operational and maintenance needs in relation to all other operations and maintenance activities (WAC 246-290-100).

Chapter 3: Construction Documents

Construction documents, such as detailed design drawings and specifications, **must** identify how specific projects will be constructed and satisfy the requirements and conditions established in the project report or the water system plan (WSP) (WAC 246-290-120). This chapter explains what should be in all water-facility construction documents. See Chapter 2 and WAC 246-290-110 for project report requirements.

3.0 Relationship to Water System Plan

If a current and approved WSP describes the water system's design and construction standards, DOH expects construction documents to satisfy those minimum standards and comply with chapter 246-290 WAC.

You do not have to duplicate detailed plans and specifications from the WSP on construction documents. However, you should cross-reference the design and construction standards section of the WSP on the construction drawings. DOH expects purveyors to give contractors the information referenced in their WSPs. Refer to Chapter 7 of the *Water System Planning Handbook* (DOH 331-068) for additional guidance on planning requirements for design and construction standards.

If a purveyor must have a WSP, DOH will not review construction documents unless the purveyor has a current, approved WSP that adequately addresses the project on file with DOH (WAC 246-290-120(3)). If an existing water system does not have such a plan, DOH may enter into a compliance agreement granting the purveyor time to complete it.

3.1 Submittal to the Department of Health for Review and Approval

All water system projects, except those exempted under WAC 246-290-125 **must** receive DOH approval **before** construction starts (WAC 246-290-120). DOH expects projects exempted from approval to meet the appropriate, applicable design criteria.

DOH recommends you submit construction documents in time to allow sufficient review so you get the approvals **before** bid solicitation starts. If you want to keep a stamped **"DOH Approved"** copy for your file, submit two complete sets of construction documents. DOH expects to take no more than 30 days for standard reviews of project reports and construction documents. If you fail to obtain approval prior to soliciting bids, the utility may have to solicit new bids or deal with significant change orders or contract amendments.

Water systems and their consultants should refer to WAC 246-290-120 for submittal requirements. DOH may return construction documents that don't meet these requirements to the submitter without engineering and compliance review (see Section 1.5). You can expect incomplete submittals to delay DOH review and approval.

3.2 Design Drawings

DOH expects all design drawings to conform to the established standards of the engineering profession. Engineers should employ the same standards of care for design drawings as they do for the project design.

3.2.1 Design Drawing Requirements

Each design-drawing package you submit for DOH approval should include both of the following:

1. A location plan indicating the location of the water system.
2. A more detailed service-area map showing the service-area boundary and the location of each project element.

Include all the following features on each design drawing you submit to DOH for approval:

- Name of project.
- Name of the municipality, association, individual, or other entity that legally own the water system.
- Scale.
- North arrow, where applicable.
- Date.
- Name, address, and phone number of the design engineer or consultant firm.
- Revision block with the initials of the design engineer and drafter.
- The original stamp and original signature of the design engineer. See the engineering registration requirements of Washington State in WAC 246-290-040.
- Location of all applicable easements, right of ways and property lines within the project area, where applicable.
- The 100-year flood elevation within the project area, where applicable (applies particularly to new water sources).
- Seismic design standards for the location where the facility will be built. Additional seismic design requirements are in Section 13.5.

In addition, DOH expects all drawings to be legible. If not, DOH may return them to the submitter without review.

If the submittal is for DOH review and comment only (not for approval), stamp the submission **Preliminary: For Review Only.** Be sure to communicate this to DOH regional staff at the time of submission.

3.3 Project Specifications

DOH expects specifications submitted for approval to include the following (items 5, 7, and 9 are required):

1. Name of the project.
2. Name of the municipality, association, individual, or other entity that legally owns the water system.
3. Date.
4. Name, phone number, and address of the design engineer.
5. The original stamp and original signature of the design engineer. See the engineering registration requirements of Washington State in WAC 246-290-040.
6. A provision for the contractor to submit shop drawings for review by owners and design engineers.
7. A detailed description of all equipment and water system start-up testing, disinfection and inspection (final acceptance) procedures (see WAC 246-290-120(4)(c)).
8. A summary of the means and methods for maintaining water service throughout the construction period, if necessary.
9. Components in substantial contact with potable water **must** be certified under ANSI/NSF Standard 61 (WAC 246-290-220).

3.4 Change Orders

Purveyors **must** submit each change order (contract addendum) that significantly alters the scope of the project, drawings, or specifications to DOH for review and approval (WAC 246-290-120(4)(d)).

Examples of changes considered "significant" and, therefore, subject to DOH approval, are:

1. Change in treatment process.
2. Change in type of chlorination or disinfection process used.
3. Change in elevations of tank or booster stations.
4. Change of materials that are in direct contact with finished water.
5. Change in control systems or control strategies.
6. Change in size for a storage tank.
7. Change in designated pumping capacity.

You may note changes not considered "significant" on the record drawings (as-builts) upon project completion. Examples include adjustments to valve locations, piping configurations, security fencing materials, and a different pump model with the same pumping characteristics.

For guidance on a particular change order, contact the DOH regional engineer responsible for the county in which the project is located (see Table 1-1).

3.5 Contracted Components for a Project

Submit construction documents (bidding package) that call for contractor-supplied construction drawings and specifications to DOH for review and approval, even if they aren't available until a later date. In some cases, contractor supplied components have been approved for categorical use (such as some reservoirs). This pre-approval can reduce the amount of information that you must submit. However, you must still include site-specific design information along with standard specifications in the construction documents you submit.

References

WSDOH. 1997. *Water System Planning Handbook*, DOH 331-068, Washington State Department of Health, Olympia, WA.

Chapter 4: Review and Approval of Project Reports and Construction Documents

This chapter covers the review and approval process for project reports and construction documents (WAC 246-290-110 through 140). See Chapter 2 for details on project reports and Chapter 3 for details on construction documents.

4.0 When to Submit Required Documents

With few exceptions (see Section 4.4), DOH requires engineers to submit project reports and construction documents whenever they propose a water system extension or improvement, or develop a new water system. This includes any treatment facilities, coatings, or additives that will be in contact with the water; source and storage facilities; transmission and distribution pipes; and pumping facilities with associated controls and alarms. Engineers also may be required to submit project reports when addressing a water system problem or customer complaints.

4.1 Coordination with Local Approving Authorities

Construction projects may be subject to local permits or approvals. Compliance with DOH requirements does *not* guarantee compliance with local rules. Purveyors are responsible for ensuring projects follow local approval processes. You can usually get information on the local approval process from county building departments and environmental health programs.

4.2 Project Report Requirements

DOH recommends that the design engineer check with the appropriate regional engineer to determine whether a project report is required (see Table 1-1).

DOH requires a project report, presenting design concepts and criteria, for all source-of-supply and treatment projects, and facility additions on water systems not required to have a water system plan (WSP). Project reports may also be required for other major projects when sufficient detail on analysis of alternatives is not included in the WSP. More detailed submittal requirements for project reports are in Chapter 2.

Water systems **must** submit project reports or WSP amendments to DOH whenever they anticipate providing water service to new lots or developments not addressed in a previously approved WSP, whether or not new facilities are required (WAC 246-290-100).

4.3 Screening and Review Process

DOH puts all engineering documents through a screening process before they enter the review process.

4.3.1 Initial Screening

You should submit project reports and construction documents to the appropriate DOH regional office (see Table 1-1). In our initial screening, we ensure the submittal is complete and confirm that DOH approval is required.

The DOH regional office will review the submittal for the following:

1. A completed *Project Approval Application Form* (DOH 331-149). DOH uses this form for administrative purposes. It is available on the DOH Web site (see Appendix A).
2. The submittal requires DOH approval (chapter 246-290 WAC). There is a fee associated with the review. Review fees are in WAC 246-290-990.
3. A qualified professional engineer licensed in Washington State prepared the documents. The engineer **must** seal, sign, and date the documents (WAC 246-290-040).
4. The DOH-assigned project identification number is on the transmittal letter or memo. (This is for re-submittals only. DOH assigns an ID number after initial documents are submitted.)
5. A water rights self-assessment is included, if necessary. If you already submitted a current water rights self-assessment to DOH, note that fact in your submittal (WAC 246-290-120(7)).

4.3.2 Water System Plan Screening

DOH expects purveyors to determine whether submitted project reports or construction documents are adequately addressed in a WSP (WAC 246-290-110(3) and 120(3)).

In summary, the screening consists of the following questions:

Community Water Systems

1. Is a WSP required? All new or expanding community water systems **must** have an approved, current WSP (WAC 246-290-100(2)). In general, "expanding" is any activity that leads to an increase in service area or the number of service connections currently authorized by DOH. For a detailed definition of "expanding," and exceptions to the definition, see WAC 246-290-010.
2. Has DOH approved the WSP? Is the WSP current? "Current" means approved within the last six years.
3. Does the WSP capital improvement schedule identify the project?
4. If the WSP is not current, is the purveyor in conformance with the DOH-approved WSP development schedule?

If the answer to question 1 is "yes" and the answer to any other questions is "no" the design engineer should contact the DOH regional office for further guidance (see Table 1-1).

Nontransient Noncommunity Water Systems

1. If the project is a new nontransient noncommunity water system, is there an approved small water system management program (SWSMP)?
2. If not, does the submittal include an SWSMP? See WAC 246-290-105(3).

If the answer to both questions is "no," the design engineer should contact the DOH regional office planner for further guidance (see Table 1-1).

See Section 1.3 for more information on how project reports and construction documents relate to WSPs.

4.4 Submittal Exceptions: Miscellaneous Components and Distribution Mains

For the following types of projects, purveyors are **not required** to submit project reports or construction documents to DOH for review and approval (WAC 246-290-125(1)):

1. Installing valves, fittings, meters, and backflow prevention assemblies.
2. Installing hydrants.
3. Repairing a water system component or replacing it with a component of similar capacity and materials described in the original approved design.
4. Maintaining or painting surfaces not contacting potable water.

Purveyors may elect not to submit project reports or construction documents for new distribution mains or larger-capacity replacement mains if they meet the following conditions (WAC 246-290-125(2)):

1. The water system has a currently approved WSP that includes standard construction specifications for distribution mains and an analysis of the hydraulic capacity of the basic transmission and distribution main configuration for the water system.
2. The water system maintains a completed *Construction Completion Report for Distribution Main Projects* (DOH 331-147) on file for each such project.

4.5 Submittal Exception Process for Distribution-Related Projects

Purveyors may choose not to submit distribution-related projects for review and approval if they meet all the requirements of WAC 246-290-125(3). The distribution-related submittal exception process requirements and potentially eligible projects are described below.

4.5.1 Distribution-Related Projects Eligible for the Submittal Exception Process

Distribution-related projects are defined in WAC 246-290-010. Eligible projects are limited to:

- Storage tanks
- Booster pump facilities
- Transmission mains
- Pipe linings
- Tank coatings

You **must** always submit source-of-supply (new wells or springs, refurbished wells, surface water intakes, interties) and water-quality treatment projects (chlorination, filtration plants, iron and manganese treatment, and ozonation). Source-of-supply projects include developing a new source or redeveloping an existing source, and projects that result in capacity increases or decreases that affect a water system's ability to serve customers.

4.5.2 Eligibility Criteria for the Submittal Exception Process

To qualify for the Submittal Exception Process, the purveyor **must** provide evidence of, and maintain compliance with, all the following conditions (WAC 246-290-125(3)):

1. The water system has a current DOH-approved WSP (WAC 246-290-100).
2. The purveyor requested the submittal exception process and DOH approved the request. See Section 4.5.3 for more details on this requirement.
3. The approved WSP includes design and construction standards for distribution-related projects (WAC 246-290-100(5)(b)).
4. The water system has a designated review engineer who is a salaried or contract employee. The review engineer must be a professional engineer, licensed in Washington State. The review engineer and design engineer must be different people.
5. The WSP identifies projects such as new transmission mains, booster pump stations, and storage tanks in the capital improvement program.
6. The purveyor maintains a summary file for each project and makes them available for DOH review. Each project summary file contains an *Engineering Design Report Form* (DOH 331-122) * completed for the project.
7. The purveyor completed a *Construction Completion Report for Submittal Exception Process Form* (DOH 331-146) * for each project and if projects include new storage tanks or booster pump stations submitted them to DOH.

8. If necessary, the purveyor completed a *Water Facilities Inventory Form* * (WAC 246-290-120(6)).
9. The water system has a "green" operating permit.

***** These forms are available on the DOH Web site (see Appendix A).

4.5.3 Water System Must Ask to Use the Submittal Exception Process

Water systems that meet the eligibility criteria and intend to follow the submittal exception process **must** make an initial written request to DOH on the *Water System Plan Submittal Form* (DOH 331-397) (available on the DOH Web site (see Appendix A)).

The request **must** show that the water system meets the eligibility criteria. To do so, reference a current approved WSP that shows a professional engineer performs project review and approval functions, as a salaried employee or under contract. If the approved WSP does not identify the engineer, the water system may send DOH an addendum to the WSP.

Most initial requests go through the routine WSP update process (WAC 246-290-125(3)(b) and (c)). However, some initial requests require a significant amendment to the currently approved WSP to satisfy design and construction standard requirements (see Chapter 7 of the *Water System Planning Handbook* (DOH 331-068)).

4.5.4 Design and Construction Standards for Reservoirs and Booster Pump Stations

As noted in Section 4.5.2, (item 3), to qualify for the Submittal Exception Process, the purveyor **must** include design and construction standards for distribution-related projects in an approved WSP (WAC 246-290-100(5)(b)).

DOH expects the following items to be part of the WSP narrative:

1. Reservoirs:
   - General location of tank sites.
   - Overflow and base elevations.
   - Map of service area indicating elevations of service connections.
   - Basis for sizing the storage volumes needed.
   - Hydraulic analysis of the water system or individual pressure zones evaluating the storage improvements.

2. Booster Pump Stations (BPS):
    - General location of BPS sites.
    - Sizing basis for BPS capacities needed.
    - Hydraulic analysis of the water system or pressure zones evaluating the effect of BPS operation.

The following items should be part of the WSP standard specifications:

1. Reservoirs
    - Standard tank details, including level controls, high and low level alarm, external level indicator, access hatch, vent, drain, overflow (include sizing) drain and outfall, and access ladder.
    - Material specifications for tanks to be used together with construction specifications (concrete, steel, other). ANSI/NSF Standard 61 certified materials for all surfaces in substantial contact with the water.
    - Specifications for all coatings, including application, curing, and ANSI/NSF compliance. Water quality testing needed before activating tanks, such as volatile organic chemicals.
    - Leakage testing procedures, per AWWA, and disinfection procedures (include disposal specifications).
    - Site piping plans (generic). Also include isolation valving, sample taps (type and location), provision to force circulation in tanks, piping material specifications for pipes under the foundation slab, in the tank or in the yard.
    - Geotechnical considerations to be addressed, such as bearing strength and seismic considerations.
    - Water system-specific water quality concerns affecting treatment, such as coliform testing, chlorine residuals, pH, disinfection byproducts, and contact time requirements.
2. Booster Pump Stations:
    - Performance specifications for booster pumps, overload capacity, and minimum shutoff heads.
    - Electrical specifications, control strategies, and mechanisms.
    - Pipe material, construction standards, and specifications for internal BPS piping.
    - Specifications or standards for meters, control valves, and other appurtenances.
    - General structural and construction specifications and standards for BPS housing.

4.5.5 Rescinding Submittal Exception Authority

Purveyors must meet the eligibility criteria in Section 4.5.2 for DOH to exempt them from the engineering document review process. To maintain exception status, a purveyor must continue to meet the eligibility criteria. DOH will no longer consider a water system eligible for submittal exceptions if documentation indicates it is not maintaining compliance with the eligibility criteria or conditions. At that point, the water system must submit all engineering documents (project reports and construction documents) to DOH for approval until it re-establishes compliance with the eligibility criteria.

4.6 Source Approval and Water Rights

If a project involves source approval, DOH requires the water system to submit a *Water Rights Self Assessment Form*. If the form is not included with the request for new source approval, DOH may return the project documents to the purveyor or hold them on file until we receive a completed *Water Rights Self Assessment Form*. This form is on the DOH Web site (see Appendix A).

If a project involves an existing unapproved source, DOH will route the *Water Rights Self Assessment Form* to the Department of Ecology for review. If a water system currently uses such a source, a provisional "as-built" approval may be given. In addition, DOH will update the water system's *Water Facilities Inventory Form*, if necessary. Unapproved sources remain subject to water quality monitoring requirements. DOH cannot approve any increase in water system source capacity without evidence of adequate water rights. If the source cannot be approved for reasons other than water rights (see WAC 246-290-130(1)), DOH may require the source to remain disconnected from the water system's distribution system, or require it to be physically disconnected. Source approval requirements are in Chapter 7 and Appendix F.

4.7 Resolving Disputed Department of Health Review Decisions

When the DOH review engineer and the purveyor's consultant cannot reconcile a difference, the purveyor may formally appeal DOH's decision through the procedures adopted in chapter 246-10 WAC). However, DOH recommends that purveyors use the following dispute resolution process before they resort to formal procedures:

1. If the DOH review engineer determines that the proposed design does not meet DOH regulatory criteria, or acceptable engineering practices, the DOH engineer will explain, in writing, the basis for denying the approval.
2. If the water system, its design engineer, or consultant (utility project engineer) disagrees with the DOH engineer's written conclusion, the utility project engineer must give the DOH review engineer the reasons for their disagreement, in writing.
3. The DOH engineer will share the information the design engineer submits with management and other professional engineers at DOH, and solicit their opinions on the utility project engineer's response. DOH will establish an official position on the specific issue.

4. After DOH establishes its position, the DOH engineer will respond to the utility project engineer. DOH usually issues its position within 21 calendar days after receiving the water system response identified in item 2, above.

If the water system, or its consultant, still disagrees with DOH's position, it can initiate the formal appeal process (chapter 246-10 WAC).

4.8 Review Fees and Invoice

DOH charges fees for reviewing project documents. These fees change periodically, so get the current fee from WAC 246-290-990 or the appropriate DOH regional office (see Table 1-1).

The review process begins when DOH receives a properly completed *Project Approval Application Form* (DOH 331-149). This form should accompany any document submitted for DOH review. See Section 4.3.1 for project submittal requirements. The form is available on the DOH Web site (see Appendix A).

After DOH completes a detailed review, it sends an approval letter or review letter to the purveyor with an invoice for the review fee. If DOH does not approve the project, the standard project review fee normally covers the cost of one re-submittal. If more than one re-submittal is necessary, DOH will charge additional fees. If the project is characterized as *non-standard* (not identified specifically in the fee regulation), DOH will assess an hourly fee and bill each review submittal separately. To keep the cost and review time to a minimum, make sure each submittal is as complete and accurate as possible. Use the *Project Submittal Checklists* in Appendix A for guidance.

4.9 Project Approval Letter and Construction Completion

When all requirements for construction documents are met, DOH will send an approval letter to the system owner, with copies to the design engineer and others, as appropriate. A typical construction-document approval includes the following enclosures:

- An invoice for the review fee, if DOH did not already send it.
- A *Water Facilities Inventory Form*, if necessary.
- A *Construction Completion Report Form*.

4.10 Construction Completion Report Forms

For clarification, there are three separate construction completion report forms. They are available on the DOH Web site (see Appendix A). Each form is used in different circumstances, so it is important to know the difference.

1. *Construction Completion Report Form* (DOH 331-121)**.** Use this form in the normal process of submitting a project to DOH for approval. It is the form referenced in WAC 246-290-120(5). DOH will send it with the construction approval document referenced in

Section 4.9 above. It is the only construction completion report that applies to source- and treatment-related construction projects.

2. *Construction Completion Report Form for Distribution Main Projects* (DOH 331-147). Use this form only for distribution main projects not requiring prior written approval from DOH. The purveyor does not have to submit this form to DOH following construction completion. However, the water system **must** maintain a completed form on file and make it available to DOH upon request. This form is referenced in the submittal exception process (see Section 4.4 and WAC 246-290-125(2)).
3. *Construction Completion Report Form for Submittal Exception Process* (DOH 331-146). Use this form only for distribution-related projects not requiring prior written approval from DOH. Distribution-related projects include booster pump stations, storage tanks, internal tank coatings, and transmission mains. The purveyor **must** submit this report to DOH after constructing new storage tanks or booster pump stations, but only maintain a completed form on file for other distribution-related projects (WAC 246-290-125(3)(f)). This form is used in the submittal exception process (see Section 4.5 and WAC 246-290-125(3)).

References

WSDOH. 1997. *Water System Planning Handbook*, DOH 331-068, Washington State Department of Health, Olympia, WA.

Chapter 5: Water Demand Requirements

To size any water system or its component parts, an engineer **must** estimate the amount of water the water system expects its customers to use (WAC 246-290-221). This chapter provides basic, conservative water-demand design criteria engineers may use if they lack information that is more appropriate.

In order of preference, the information sources for water demand estimates are:

1. Metered water-production and use records.
2. Comparable metered water-production and use data from analogous water systems. See WAC 246-290-221(3)(a) and Section 5.2.3.
3. The criteria presented in this chapter.

5.0 Applicability

Engineers use water demand estimates to design new water systems or specific additions to existing water systems. The design criteria in this chapter may need to be modified when used with longer-range demand forecasting methodologies, especially when considering water-use efficiency practices. This chapter addresses design flows for residential demands and selected transitory uses. It also provides limited information on water demands associated with nonresidential uses (industrial or commercial).

5.1 Estimating Water System Demands

Engineers need water demand estimates to size pumping equipment, transmission lines, distribution mains, and water storage facilities properly. Designs need to include sizing criteria that account for water uses during the highest demand periods. The design information should be sufficient to estimate peak hourly demand (PHD) and the maximum day demand (MDD) over the year. There is no substitute for reliable and accurate meter records for estimating future demands. When reliable water demand information is available for a given water system, the engineer **must** use it for the water system design (WAC 246-290-221).

All water systems **must** have totalizing source meters calibrated to industry standards (WAC 246-290-496(3)). For example, water systems should calibrate 4-inch diameter and larger meters at least every two years (AWWA 1999). Section 5.3 provides detail on using historical water meter records to estimate demand.

Water demands (average day demand (ADD), MDD, and PHD) may vary considerably between water systems. Therefore, it is often difficult to apply meter data from one water system to another.

The reasons for these variations include:

- Climate (evaporation, evapotranspiration, temperature, precipitation, wind, and other factors).
- Socioeconomic influences (property values, economic status, residential densities).
- Degree of recreational or seasonal uses.
- Water system pressure. Very high water system pressure can increase distribution system leakage.
- Water pricing structure (inclining block, declining block, or flat rates).
- Land use (lot size, type of development, agricultural practices, and other considerations).
- Condition of the distribution system (leakage rates, corrosion problems, and other factors).
- Water use efficiency practices.
- Soils and landscaping.

Section 5.2.3 provides more detail on the use of information from analogous water systems.

5.2 Residential Water Demand Design Criteria

Residential demand is the largest portion of total demand for most water systems. It forms the basis for most water system designs, especially smaller water systems. The design engineer with adequate historical service or source meter records can usually estimate residential demands with reasonable accuracy. Nonresidential demands related to industrial, commercial, and similar types of uses are also important and need to be estimated. Chapter 6 addresses residential and nonresidential demands on an equivalent residential unit (ERU) basis.

There is no substitute for reliable and accurate meter records for estimating future demands. For existing, expanding water systems, you **must** use metered water-use records to identify the MDD and ADD for the water system (WAC 246-290-221(1)). Service meter records can be used to estimate demands. Source meter records, are usually more prevalent and may be used. While daily source meter readings can provide an accurate estimate of daily demand, water systems **must** read source meters at least monthly (WAC 246-290-100(4)(b) and 105(4)(h)). In some cases, water systems may have to take readings more frequently to meet Department of Ecology requirements (WAC 173-173-060).

For new water systems with no source meter records, the design engineer can use information from analogous water systems or the information in Appendix D to estimate ADD and MDD for residential connections (WAC 246-290-221(3)).

Note: *The information in Appendix D is based on a 1994–1995 DOH assessment of residential water demand in Washington that did not specifically address commercial and industrial demands. This assessment revealed that water demand for single-family residential connections correlates to average annual precipitation and, to a more poorly defined degree, lot size. Section 5.2.3 provides more detail on the use of information from analogous water systems.*

5.2.1 Maximum Day Demand

Engineers **must** design water system source, treatment, and equalizing storage so that together they can meet the MDD for the water system (WAC 246-290-222). Most existing water systems **must** use metered records to estimate their MDD (WAC 246-290-221(1)).

Daily service meter records can provide an accurate estimate of MDD for a water system if all services are metered, the meters are read daily at the same time each day, and distribution system leakage is added to the total volume computed from the daily service meter records. This approach is impractical for most water systems because they usually read service meters on a monthly, bi-monthly, or quarterly basis. In addition, quantifying distribution system leakage (DSL) for peak periods of demand can be difficult as discussed in Section 6.7.5.

Daily source meter records can also provide an accurate estimate of MDD for the water system. However, even daily meter readings can result in inaccurate MDD estimates if the water system operates sources intermittently, does not collect meter readings at the same time every day, or does not include changes in storage volume over time. Section 5.3 includes additional information on using metered data to estimate MDD.

Lacking daily source meter records, you can use monthly source meter records to estimate MDD for the water system. Water systems **must** read source meters at least monthly (WAC 246-290-100(4)(b), 105(4)(h), and WAC 173-173-060). If you use monthly source meter records, you need a peaking factor to estimate the MDD from the maximum month's average day demand (MMAD). A review of water systems in Washington over multiple years showed two important elements:

1. MDD to ADD ratios are greater in Eastern Washington.
2. Fluctuations in water demand within one month are greater in Western Washington.

Based on the information available, DOH recommends a MDD to MMAD peaking factor of:

- 1.7 for water systems in Western Washington.
- 1.3 for water systems in Eastern Washington.

Note: *The pre-1986 sizing guideline of 800 gallons per day (gpd)/connection for MDD in Western Washington and 1,500 gpd/connection for MDD in Eastern Washington was inadequate for some water systems' source and storage facilities. In a few isolated cases in Western Washington, the MDD has been as high as 2,000 gpd/ connection. In Eastern Washington, the MDD for some water systems has been as high as 8,000 gpd/ connection. Design engineers should recognize that some water systems are outside the norm and will have much greater water demand.*

Depending on the design and operation of the water system, the source or sources may not be able to provide the needed MDD. Source and equalizing storage capacity **must** meet at least the MDD for the water system (WAC 246-290-222). DOH **recommends** that engineers design water systems so that source capacity alone is able to meet, and preferably exceed, the MDD. Section 9.0.3 explains how to use multiple day demand information to size multiple-day equalizing storage.

There are several issues related to using storage to meet multiple days of peak demand.

- Long storage times may lead to water quality problems such as loss of disinfectant residual, biological growth, and formation of disinfection byproducts (see Section 9.9).
- There is an increased risk of low water system pressure and possible water use restrictions in future years if the needed storage volume is underestimated.
- The more a utility relies on long-term storage rather than sources to meet MDD, the longer it will take to replenish depleted storage. Fire protection authorities advise water systems to replenish fire suppression storage within 24-hours. This may be impossible during periods of high demand if the sources cannot provide flow rates equal to or exceeding the MDD.

5.2.2 Average Day Demand

Engineers **must** use metered use records to quantify the ADD for most water systems (WAC 246-290-221). For new water systems without metered data, design engineers can use analogous water system data or the information in Appendix D to estimate the ADD for residential connections.

Information in Appendix D indicates that ADD for single-family residential connections correlates with average annual rainfall. You can get temperature and precipitation data for Washington State from the National Oceanic and Atmospheric Administration-National Climatic Data Center, and the Western Regional Climate Center. See Appendix C for contact information.

5.2.3 Analogous Water Systems

Lacking metered water use records, engineers may use comparable water use data from an analogous water system (WAC 246-290-221(3)). Because existing water systems must have and read their existing source meters, there is no need to go elsewhere for production or demand information. Analogous water system information only applies to the design of new water systems. To be considered analogous, water systems **must** have similar characteristics including demographics, housing sizes, income levels, lot sizes, climate, water-pricing structure, conservation practices, use restrictions, and soils and landscaping (WAC 246-290-221(3)(a)).

- Demographics are the vital statistics of human populations such as size, growth, density, and distribution. Demographics change with the nature of the development. Population densities are different from single-family to multifamily residences, from housing provided for families to housing provided for single occupancy, and from individual lots to mobile home park developments.

- Housing sizes often relate to the income levels of the residents. Middle-income residents typically occupy 1,500 to 3,000 square foot homes with moderate sized lawns. Higher income residents occupy homes larger than 3,000 square feet, usually with larger lots. With respect to water use, the greatest effect of income level is probably landscaping. To protect their investment and property values, residents may use significant amounts of water.

- Section 5.2.3 recommends increasing water supply to lots greater than 2.5 acres (mainly in Eastern Washington). A major factor in water use related to larger lot sizes is in the irrigated area (lawns, gardens, and agricultural uses). However, it is possible to Xeriscape (use native flora, rockery, and pavement) multi-acre tracts with very little need for supplemental irrigation.

- Climate significantly effects water use. High temperatures and low precipitation usually lead to an increased water use. To be considered analogous, water systems should have similar monthly and average annual temperature and precipitation. In areas where freezing temperatures are prevalent in winter, high demands may occur if users allow faucets to run to prevent freezing. You can also expect water demand to increase during the winter for water systems serving winter use activities, such as a ski resort.

- Water pricing structure relates to the use of "inclining block rates" versus "declining block rates." Both require the use of individual meters. For "flat rates," meters are most often not present and analogous water demands are more difficult to predict. To be considered analogous, the existing and proposed water systems should provide the same level of metering and have similar rate structures.

- The analogous water system's conservation practices should be the same as the proposed water system. These practices include, but are not limited to, alternate day watering schedules, installing low-water-use fixtures, toilet-tank displacement devices, leak detection, and water demand reduction programs. Water use restrictions should be established that are the same for any voluntary or mandatory curtailment measures requested of analogous water system consumers. These may be in community covenants, bylaws, local ordinances, or on property deeds**.** It is very important to determine if the restrictions are enforceable. A legal opinion may be necessary to determine equivalent enforceability.

- Soil types and landscaping can affect irrigation demands. Moisture retention and evaporation losses from sands and gravels differ from loams, silts, and clays. When designing a water system, engineers should check with the local Cooperative Extension office to determine and evaluate variables that may affect water demand. For example, water demands for landscaping vary largely between natural flora and more water-dependent plants.

- The analogous water system's utility maintenance practices should be considered. These practices include the seasonality, frequency of, and volume of water used for line flushing, exercising hydrants and valves, and cleaning tanks.

Water-use patterns between water systems vary for more reasons than those presented above, and in Section 5.1. Sociological factors also play a role. It is nearly impossible for a design engineer to predict the mind-set or water use ethic of consumers on a new water system. When basing a water system design on characteristics analogous to another water system, DOH recommends conservative water demand estimates. A safety factor is appropriate even if the proposed water system incorporates the same enforceable water use efficiency practices and use restrictions as the identified analogous water system. It may be wise to discuss this design approach with your DOH regional engineer (see Table 1-1) early in the design phase of a project.

Note: *The design engineer should always discuss the design basis with the client to determine if it needs a specific safety factor (relative to the nature of the project), and what that factor should be. The engineer and the client should also be clear about:*

1. *The best way to communicate realistic service expectations to the lot purchaser.*
2. *How to notify lot owners or water system users about any constraints on water usage, even to the extent of requiring notice on property titles or other documentation.*

5.2.4 Peak Hourly Demand

Engineers need PHD estimates to size equalizing storage, transmission lines, distribution mains, and some pumping facilities. The water system **must** be able to provide PHD while maintaining a minimum pressure of 30 psi throughout the distribution system (WAC 246-290-230(5)). Water system specific diurnal demand curves can be developed and used to estimate PHD (AWWA 2004). Engineers usually need multiple diurnal demand curves because demand changes seasonally (AWWA 2004).

Lacking documented information, engineers may use Equation 5-1 to determine PHD flows. This equation is consistent with the maximum instantaneous demand values presented in previous editions of the state's design guidance manuals (WSDSHS 1973; WSDSHS 1983). Equation 5-1 accounts for the ranges of peak-hourly to MDD ratios reported as a function of water system size and by various water systems in Washington.

Equation 5-1: Determine PHD

$$PHD = (MDD/1440)\,[(C)(N) + F] + 18$$

Where	**PHD**	=	Peak Hourly Demand, (gallons per minute)
	C	=	Coefficient Associated with Ranges of ERUs
	N	=	Number of ERUs
	F	=	Factor Associated with Ranges of ERUs
	MDD	=	Maximum Day Demand, (gpd/ERU)

An ERU is the amount of water consumed by a typical full-time single-family residence. See Chapter 6 for more information on ERU. It explains how to analyze water demand and assess water system physical capacity in ERUs when a water system has multiple types of demand (residential, commercial, industrial, and others).

Table 5-1 identifies the appropriate coefficients and factors to substitute into Equation 5-1 for the ranges of single-family residential connections:

Table 5-1

Number of ERUs (N)	C	F
15 – 50	3.0	0
51 – 100	2.5	25
101 – 250	2.0	75
251 – 500	1.8	125
> 500	1.6	225

5.2.5 Adjusting PHD for Lots Larger than 2.5 Acres in Areas Receiving Average Rainfall of 20 or Less Inches per Year

Engineers should determine additional PHD flows for water systems in areas receiving 20 or fewer inches of rainfall per year (mostly in Eastern Washington) that:

- Do not have a separate irrigation system available for each lot.
- Have lot sizes equal to, or greater than 2.5 acres.

An additional flow of 10 gpm should be added to the calculated PHD for each acre to be irrigated in excess of the base value, calculated as the product of 2.5 times the number of connections.

If irrigation is not permitted on more than 2.5 acres per connection, or if additional management controls are instituted, then such information should be noted on restrictive covenants, water user agreements, or some other legally enforceable agreement between the lot owner (or water customer) and the water system. This information is important when requesting approval of project reports and water system plans.

5.3 Design Criteria Based on Documented Water Use

Water system design criteria may be adjusted for water systems that seek additional service connections. Such adjustments **must** be justified through review of historical water uses that provide updated water system design peaking factors, and other factors (WAC 246-290-221(4)). While it is necessary to use accurate and extensive meter information to support any adjusted design criteria, there is no established formula or criteria for making such adjustments.

An "expanding" water system is one that installs new source, transmission, storage, treatment, or distribution facilities that allow it to increase its service area or number of approved connections. A planning documents is required for "expanding" water systems (WAC 246-290-100(2)(e)). An engineer **must** prepare the historical water use analysis and, in most cases, the planning document. Both **must** address the capacity elements in WAC 246-290-100(4).

In general, the lower limit for MDD is 350 gallons/day/residential connection (WAC 246-290-221(4)). This demand estimate is consistent with the Department of Ecology on household water uses for developments that restrict outside irrigation uses. There may be some projects with sufficient verified information (meter records, minimum of two years of data) to support a maximum day demand of less than 350 gallons/day/ERU. The data may only be used in support of expansion for that specific water system (WAC 246-290-221(4)).

5.3.1 Basic Elements of Water Demand Documentation

Engineers using historical water use records to design future water system facilities should increase confidence levels by validating the information. Given all the variables that affect water demand (see Section 5.1), design criteria based on historical data should include a reasonable margin of safety. The more detailed the historical use records are, the smaller the margin of safety needs to be. The analysis of historical water demand should include:

1. Additional services should be based on actual water demands. Water systems cannot justify new services solely by committing to implement a water use efficiency program. The analysis also should demonstrate the results of successful water use efficiency efforts with corresponding reductions in water use.
2. The historical water use analysis should be based on meter readings covering at least two, but preferably more years. The meter readings should include daily use data for the peak usage period and weekly or monthly usage during the rest of the year. Most community water systems experience peak demand from June through September. Other water systems, such as ski resorts, may experience peak demand during the winter.

For most water systems, the historical water use analysis **must** quantify distribution system leakage and total authorized consumption (WAC 246-290-820). See Section 6.4.6 for information on distribution system leakage and authorized consumption.

3. Water demand data **must** be correlated with the number of full- and part-time residential service connections actually in use when the data was collected (WAC 246-290-221(1)). To quantify residential demands more clearly, the analysis should separate industrial, commercial, or other water demands from residential demands.
4. The analysis should address potential changes in demand (see Section 5.3.2).
5. Rainfall and temperature data should be reviewed to verify their affect on water system demand. Rainfall and cool weather usually decrease water demand. Drought also affects demand for some water systems, especially if it is severe enough to result in water use restrictions. The National Drought Mitigation Center has historical drought information you can review for this purpose. Contact information is in Appendix C.

   Engineers should compare water demand data to historical climate information to determine if it is necessary to adjust historical demand data. For example, summer temperature and precipitation data from the Office of the Washington State Climatologist will tell if it was an unusually wet or cool summer, which most likely resulted in decreased water demand.

5.3.2 Anticipated Changes in Demand

Water demand estimates should address anticipated changes as a water system matures. An analysis should address how future water-use patterns may change. For example, vacation lots may become retirement homes, or be sold as permanent residences in a phased plan for development. The analysis should consider if commercial or light industrial activities associated with full build-out of the development are intended. Adjustments to any established design criteria should reflect actual conditions. These adjustments should provide a realistic margin of safety for reasonably anticipated increases in demand. For some projects, water system demand or standby storage needs may exceed the initial estimate. This could occur when a water system experiences higher-than-expected growth, has historical supply reliability problems, or its status changes due to higher service demand (changing economic and demographic influences).

5.3.3 Demand Estimates for Water Systems with Full-time and Part-time Single-Family Residential Users

Many water systems use source meters to estimate demand. These records are straightforward when customers occupy residences throughout the year. However, when customers occupy homes intermittently, dividing total production by the total number of homes on the water system would significantly underestimate demand. For this reason, demand estimates **must** be correlated with full-time and part-time residential connections in service (WAC 246-290-221(1)).

Obtaining source meter records over any selected period is relatively straightforward. However, determining occupancy levels during that same period can be quite difficult. Water systems can use the following approaches to correlate source meter data with estimated occupancy levels. Each of these approaches has shortcomings, so DOH recommends using more than one.

- **Survey customers:** Very small water systems with about 50 or fewer connections may be able to use a survey to estimate daily or weekly occupancy for a short period of time when they can rigorously take meter readings. Because survey response rates from customers can be low, water system staff should consider observing activity at residences to confirm occupancy. If the primary capacity limitation is associated with MDD, the survey could focus on the expected peak-demand period of summer.
- **Service meter records:** Many water systems have service meters, and all municipal water suppliers **must** install meters on their direct service connections (WAC 246-290-496(2)). Water systems usually read service meters monthly, bi-monthly, or quarterly. The frequency of meter reading limits the outcome of this method. In one comprehensive study, median indoor residential water use ranged from 54 to 64 gallons per capita per day for several communities throughout the United States (Mayer et al. 1999). When water use for a residence falls significantly below this range, residents probably occupy the dwelling intermittently. Reviewing service meter records may help you select the time to use an intensive meter-reading program to correlate demand with occupancy.
- **Assume full occupancy on holidays:** For some small recreational water systems, it may be reasonable to assume that all residences are occupied during certain times of the year, such as Memorial Day or Labor Day weekends. Other water systems may be able to assume full occupancy on other days. Meter readings on those days, especially if the water system assumes high demands will occur, could help to estimate peak day demand. You should supplement this approach with a customer survey on these target weekends.
- **Demand patterns:** Demands that vary significantly between billing periods could indicate an intermittently occupied residence.
- **Tax, voting, and other public records:** These may help to determine occupancy levels. However, there are several shortcomings to using public records to estimate occupancy. For example, people who live part-time in Washington and part-time in a warmer climate appear as full-time residents on assessor and voting records. Rental properties are another example. Similar to vacation homes, the assessor sends tax records for rental properties to owners at their primary residences. Renters may not be registered to vote where they reside.

Ultimately, the water system must permit new connections and manage demand in a manner that does not exceed the physical capacity of the water system or water right limitations.

5.4 Estimating Nonresidential Water System Demand

Nonresidential water demand is the water consumed by users other than single or multifamily residential units. They can include:

- Commercial facilities (retail or wholesale businesses, restaurants, hotels, office buildings, and car washes).
- Industrial customers that require process water.
- Public facilities (schools, public hospitals, governmental offices, parks, landscaped roads, and cemeteries).
- Other large users, such as farms with irrigated crops.
- Recreational users (campgrounds, RV parks, and seasonal rental units).

Water systems that consist solely of these types of demand are usually classified as "transient noncommunity" or "nontransient noncommunity" water systems (see WAC 246-290-020). Engineers should use different approaches to determine water demands for these customer types because they do not follow residential water use patterns. You may have to use an analogous water system's nonresidential use records, or meter records directly associated with the nonresidential use to get PHD, ADD, and MDD determinations.

5.4.1 Procedures for Estimating Nonresidential Demands

Design engineers can base ADD and MDD estimates for **new** nonresidential water systems on similarly sized facilities or water systems. Table 5-2 offers reasonable estimates of average water demands for a variety of uses. Engineers can use it as a guide for preparing water demand estimates. However, for some facilities, they may have to add the peak flow rates of all fixtures to calculate the maximum flow rate. They may also have to account for outdoor watering needs and fire protection requirements.

Engineers may find other information sources more valuable than Table 5-2. The designer should review several information sources to ensure compliance with local codes or to account for water use efficiency practices they propose for the development. Recommended resources include the:

- ***Uniform Plumbing Code*** (UPC). Under Appendix A of the UPC, engineers can total the number of water supply fixtures in a building and convert it to an estimated peak water system demand. Local jurisdictions may require a water system to use the UPC to estimate demand.
- **Department of Ecology**. Engineers should consult any specific water-demand estimates the Department of Ecology prepared to see if they reflect adjustments for the proposed water use efficiency practices.

Table 5-2: Guide for Average Daily Nonresidential Water Demand

Type of Establishment	Water Used (*gpd)*
Airport (per passenger)	**3 - 5**
Apartment, multiple family (per resident)	**50**
Bathhouse (per bather)	**10**
Boardinghouse (per boarder)	**50**
Additional kitchen requirements for nonresident boarders	10
Camp	
Construction, semi-permanent (per worker)	50
Day, no meals served (per camper)	15
Luxury (per camper)	100 - 150
Resort, day and night, limited plumbing (per camper)	50
Tourist, central bath and toilet facilities (per person)	35
Cottage, seasonal occupancy (per resident)	**50**
Club	
Country (per resident member)	100
Country (per nonresident member present)	25
Factory (gallons per person per shift)	**15 - 35**
Highway rest area (per person)	**5**
Hotel	
Private baths (2 persons per room)	50
No private baths (per person)	50
Institution other than hospital (per person)	**75 - 125**
Hospital (per bed)	250 - 400
Lawn and Garden (per 1,000 sq. ft., Assumes 1-inch per day (typical))	**600**
Laundry, self-serviced (gallons per washing per customer)	**50**
Livestock Drinking (per animal)	
Beef, yearlings	20
Brood Sows, nursing	6
Cattle or Steers	12
Dairy	20
Dry Cows or Heifers	15
Goat or Sheep	2
Hogs/Swine	4
Horse or Mules	12
Livestock Facilities	
Dairy Sanitation (milk room)	500
Floor Flushing (per 100 sq. ft.)	10
Sanitary Hog Wallow	100

Type of Establishment	Water Used (*gpd)*
Motel	
Bath, toilet, and kitchen facilities (per bed space)	50
Bed and toilet (per bed space)	40
Park	
Overnight, flush toilets (per camper)	25
Trailer, individual bath units, no sewer connection (per trailer)	25
Trailer, individual baths, connected to sewer (per person)	50
Picnic	
Bathhouses, showers, and flush toilets (per picnicker)	20
Toilet facilities only (gallons per picnicker)	10
Poultry (per 100 birds)	
Chicken	5 - 10
Ducks	22
Turkeys	10 - 25
Restaurant	
Toilet facilities (per patron)	7 - 10
No toilet facilities (per patron)	2 ½ - 3
Bar and cocktail lounge (additional quantity per patron)	2
School	
Boarding (per pupil)	75 - 100
Day, cafeteria, gymnasiums, and showers (per pupil)	25
Day, cafeteria, no gymnasiums or showers (per pupil)	20
Day, no cafeteria, gymnasiums or showers (per pupil)	15
Service station (per vehicle)	**10**
Store (per toilet room)	**400**
Swimming pool (per swimmer) Maintenance (per 100 sq. ft.)	**10**
Theater	
Drive-in (per car space)	**5**
Movie (per auditorium seat)	**5**
Worker	
Construction (per person per shift)	50
Day (school or offices per person per shift)	15

Source: Adapted from *Design and Construction of Small Water Systems* (AWWA, 1984)**,** and *Planning for an Individual Water System* (American Association for Vocational Instructional Materials, 1982).

- **American Water Works Association (AWWA)**. Engineers should consult AWWA for information on recently developed or updated demand estimates. This source will be especially important if current data (based on published reports and research) was recently applied to estimates that reflect water use efficiency practices, regional demographic changes, or other adjustments to previous tabulations.

  If engineers cannot find pertinent information through other sources, they can refer to AWWA guidelines in Table 5-2 and the UPC.

- **DOH Regional Office**. If information in Table 5-2 does not appear to apply to the project, engineers can contact DOH to determine appropriate criteria that may apply on a case-by-case basis (see Table 1-1).

5.4.2 Commercial, Industrial and Public Facility Demand

Water demands for commercial, industrial, and public facility categories range widely from less than, to significantly more than, a single-family residence. This is especially true for large farm irrigation needs or commercial and industrial processes. Engineers can use Table 5-2, UPC demand estimates, and other reference documents as a planning guide for water use. To estimate water demands, designers should use these planning guides together with documented water-use records for existing facilities within the water system, or comparable uses at other water systems.

5.4.3 Farming and Crop Irrigation Demand

Engineers should get help from local Cooperative Extension offices when determining water-use estimates for farms. It may be possible to find water-use records for various farm practices in the area. Table 5-2 provides some water-use references by type and number of livestock. Irrigation needs can be extremely variable and may require additional investigation.

Some variables that influence water demands for farming and crop irrigation are:

- Type of farm.
- Number and type of animals it produces.
- Type of crops it grows.
- Weather conditions.
- Geographic location.

5.4.4 Recreational Development Demand

"Recreational development" applies to facilities that individuals and families intend to use for vacations or holidays away from their normal place of residence. They vary from simple campsites suitable for tents or trailers, to elaborate communities of rustic housing equipped with most, if not all, the amenities of urban living.

Some recreational developments operate in a manner similar to a state campground. Others operate on a membership basis or sell facilities lot-by-lot, as in an ordinary residential plat. Recreational developments may be eligible for reduced water system design criteria. DOH will consider reduced-design criteria if a recreational development can show that:

1. There are clearly defined sites for each occupant. Recreational developments can define sites by surveyed lot lines, permanent site markers, or surveyed-site centerlines drawn on a map that identifies the location of each site. DOH expects the number of sites or lots for the total tract to remain the same.
2. Reduced criteria will only apply to sites intended solely for recreational occupancy. No permanent residence, no matter how small, how simple, or how rustic, is permitted on a site designated for recreational uses. Developments that will be used totally or partially in a residential manner should be designed to accommodate appropriate residential demands.
3. The acknowledged purpose of the recreational portions of the tract is to provide space for short-term or seasonal use only.
4. DOH received satisfactory documentation of claims made with respect to items 2 and 3 above. This may include a notation of the restrictions on the face of the plat, in covenants filed with the plat, or in individual deeds.

Engineers can use Table 5-2 and other information sources to estimate water uses for typical recreational facilities. For example, UPC fixture demands and the Department of Ecology wastewater flow tables (WSDOE 2008) provide typical average daily water uses for the facilities referenced. However, the MDD should be no less than 140 gpd per site or lot for recreational tracts with structures with internal plumbing suitable for short-term occupancy (cabins, houses, and trailers). DOH expects engineers to base peak hourly flows on a level that provides at least 50 percent of the comparable residential PHD associated with the size of the development. Recreational water systems usually experience peak demands during summer holiday weekends.

5.5 Water Demand Forecasting

DOH recommends using the basic planning and water-demand forecasting methodology in the *Water System Planning Handbook* (DOH 331-068).

5.6 Water Resource Issues

Pressure on the state's water resources is steadily increasing. This pressure comes from many sources including population growth, instream flows, and business needs. In 2003, the Washington State Legislature passed Municipal Water Supply – Efficiency Requirements Act, Chapter 5, Laws of 2003 First Special Session, better known as the Municipal Water Law. This law establishes greater water right certainty and flexibility for municipal water suppliers. It also required DOH to develop water use efficiency (WUE) requirements to promote good stewardship of water resources. Municipal water suppliers must consider both water rights and WUE requirements as described in more detail in the following sections.

5.6.1 Water Rights

For new sources and increases in water system capacity, engineers **must** address water rights as a part of a submittal to DOH (WAC 246-290-100(4)(f), 105(4)(e), 110(4)(e), 120(7), 130(3), and 132(3)(b)). In these submittals, the engineer must complete a *Water Rights Self Assessment Form* as part of the water rights analysis unless otherwise noted. This form is on the DOH Web site (see Appendix A). Water rights are discussed in Section 1.7, Section 2.2.5, Section 4.6, and Section 7.0.2.

5.6.2 Water Use Efficiency

Growing communities, agriculture, industry, and protecting the environment have placed emphasis on preserving water resources in Washington State. The Municipal Water Law helps address increasing competition for the state's water resources, and establishes some fundamental requirements for municipal water suppliers. DOH adopted WUE requirements in chapter 246-290 as required by the Municipal Water Law.

There are three key elements to the WUE requirements:

- **WUE Planning Requirements:** As part of a water system plan or small water system management program,. municipal water suppliers **must** collect data, forecast demand, and evaluate leakage (WAC 246-290-800). Other requirements include implementing appropriate WUE measures, such as considering rate structures that encourage WUE (WAC 246-290-810).
- **Distribution System Leakage Standard**: Municipal water suppliers **must** meet certain leakage standards to minimize water lost through distribution system leaks. Most municipal water suppliers that lose more than 10 percent of the water they produce through distribution system leakage **must** take action to reduce their leakage (WAC 246-290-820).
- **WUE Goal-setting and Performance Reporting:** Municipal water suppliers **must** set quantitative WUE goals through a public process. They **must** report their WUE efforts to their customers and DOH by July 1 every year, and make the information available to the public (WAC 246-290-830 and 840). They **must** use the online *Annual Water Use Efficiency Performance Report Form* (DOH 331-376) when reporting to DOH (see Appendix A).

In general, municipal water suppliers are publicly owned community water systems with 15 or more residential service connections. Some publicly owned noncommunity water systems are also considered municipal water suppliers. This determination is made on a case-by-case basis.

All water systems **must** install source meters (WAC 246-290-496(1)). In addition, municipal water suppliers **must** install meters on all direct service connections (WAC 246-290-496(2)). Source and service meters provide the data necessary to determine leakage, assist in managing an important resource, and enhance planning activities. Municipal water suppliers **must** meter all new service connections now and install service meters on all existing service connections by January 22, 2017 (WAC 246-290-496(2)). For more information on these WUE requirements, order the *Water Use Efficiency Guidebook* (DOH 331-375) or contact a DOH regional planner (see Table 1-1).

5.7 General Water System Reliability

The design engineer **must** address all regulatory requirements that ensure water system reliability, including sufficient source and storage capacity, pumping capacity, and hydraulic capacity applicable to the water system.

An extensive discussion on water system reliability is in the preface of this manual. Additional guidance on water system reliability is in Chapter 4 of the *Water System Planning Handbook* (DOH 331-068).

5.7.1 Water System Reliability Recommendations

Recommendations for source and water system reliability appear in various chapters of this manual. The following is a brief summary of DOH recommendations intended to promote high levels of water system reliability.

Source (refer to Chapters 5 and 7)

1. Two or more supply sources are available with a capability to replenish depleted fire suppression storage within 72-hours while concurrently supplying the MDD for the water system.
2. Combined source capacity for the water system is enough to provide the MDD in a period of 18 hours or less of pumping.
3. With the largest source out of service, the remaining source(s) can provide a minimum of ADD for the water system.
4. Pump stations have power connections to two independent primary public power sources, or have portable or in-place auxiliary power available.
5. The firm yield of surface water sources is consistent with the lowest flow or longest period of extended low precipitation on record.

Booster Pump Stations (refer to Chapter 10)

1. Multiple pumps are installed with capacity to provide the MDD of the service area when the largest pump is out of service.
2. At least 20 psi at the intake of the pumps under PHD or fire flow plus MDD rate-of-flow conditions is always maintained.
3. An automatic shut-off is in place for when the intake pressure drops below 10 psi.

4. Power connections are available to two independent primary public power sources, or there is a provision for in-place auxiliary power if the pumps provide fire flow or are pumping from ground-level storage.

Distribution Storage (refer to Chapters 5 and 9)

1. More than one gravity storage tank (wherever feasible) exists with the ability to isolate each tank while continuing to provide service.
2. Storage is sufficient to give standby capacity of at least two times the ADD for all users, and to ensure that fire suppression service will be available while not allowing pressure to drop below 20 psi at any service connection.
3. A minimum standby volume of 200 gpd per residential connection, or equivalent, is provided regardless of the capacity of the sources available.
4. An alarm system is included that notifies the operator(s) of overflows, or when the storage level drops below the point where the equalizing storage volume is depleted. This should only occur during abnormal operating conditions.

Distribution System (refer to Chapter 8)

1. Distribution mains are looped wherever feasible.
2. Pipeline velocities do not exceed eight feet per second under PHD conditions.
3. All pipelines can be flushed at a flow velocity of at least 2.5 feet per second.
4. All mains and distribution lines have appropriate internal and external corrosion protection.
5. If fire flow is provided, the engineer should conduct a hydraulic analysis to determine whether high firefighting demands may cause very low pressure (below 30 psi) in the distribution system. Very low water system pressure presents an increased risk of contamination from cross-connections and pathogen intrusion at joints.

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Chapter 6: Water System Physical Capacity Analysis: Equivalent Residential Units

This chapter presents concepts useful for determining the existing and future physical capacity of a water system.

Engineers **must** determine the physical capacity of a water system by evaluating the source, treatment, storage, transmission, or distribution components of the water system individually and in combination with each other (WAC 246-290-222). The physical components of a water system, when properly operated, provide the infrastructure for the water system's physical capacity to serve its customers under peak demand conditions.

A water system may serve a variety of customers with differing patterns of demand. Engineers should design water systems to meet the expectations of all customers. Water systems should routinely evaluate the specific water-use characteristics of their customers. This will establish or update the fundamental basis for design, and supply data a water system can use to provide the most reliable and cost-effective service.

6.0 Applicability

The approaches presented in this chapter apply to new, expanding, or existing water systems serving any combination of residential and nonresidential customers such as commercial, industrial, public facilities, recreational, or other large users.

The basic unit of a water system's physical capacity is the equivalent residential unit (ERU) (WAC 246-290-222). The number of ERUs a water system can accommodate is based on physical and legal constraints. Most of this chapter is devoted to evaluating the physical capacity of water systems.

DOH expects engineers to analyze and discuss water system physical capacity in planning documents and growth-related projects in terms of ERUs (WAC 246-290-100). There are also situations when engineers need to determine the physical capacity of a water system. For example:

- An existing water system does not have DOH approval.
- An engineer submits reports for a water system without an approved planning document.
- Project construction is complete, but the project scope changed DOH approval.
- A non-expanding water system is asked to provide service to a type of connection not identified in its planning document, or any previous project approvals.

Note: *A water system's actual physical capacity, in ERUs, is determined only after all facilities that will provide service are installed and available for use.*

6.1 Background

Design and performance elements for water systems are in chapter 246-290 WAC. Engineers use these criteria to determine what design factor(s) apply to water system designs or to determine limitations to a water system's ability to serve its customers. DOH conducts or reviews physical capacity analyses of source, transmission, distribution, storage, and treatment as a part of its design review process or while establishing a water system's growth limits.

This chapter helps engineers and water systems determine the level of service (in ERUs) associated with designing new facilities or evaluating existing facilities.

6.2 Capacity Definitions

For water systems, DOH defines "capacity" as the ability to provide service. Specific definitions in this manual include:

- **System capacity**: The "operational, technical, managerial, and financial capability" of a water system to achieve and maintain compliance with all local, state, and federal regulations (WAC 246-290-010). This broad definition of capacity covers both the physical infrastructure and the people responsible for operating and maintaining it.
- **System physical capacity or physical capacity**: The maximum number of service connections or ERUs that the water system can serve when considering the limitation of each water system component such as source, treatment, storage, transmission, or distribution, individually and in combination with each other (WAC 246-290-010).

6.3 Fundamental Design Principle for Physical Capacity Analysis

The physical capacity analysis is based on the water system's ability to meet the maximum day demand (MDD) for the entire water system. It **must** also verify that adequate distribution system pressure can be maintained under peak hourly demand (PHD) and MDD plus fire flow conditions where fire flow is provided (WAC 246-290-230).The number of customers a water system can serve depends on the characteristic water demand patterns and minimum requirements associated with design factors identified in Section 6.5. Physical capacity determinations **must** be reported in ERUs as described in Section 6.4 (WAC 246-290-222(2)).

6.4 The Concept of Equivalent Residential Units

Most water supply systems, and especially small water systems, are mostly designed to serve single-family residences. Single-family residential customers have a typical overall demand pattern. Nonresidential or multifamily (apartments and condominiums) customers may have significantly different demand patterns. Engineers should design a water system that compares nonresidential or multifamily consumer demands to average single-family residential use in terms of equivalent routine water use.

Note: *Chapter 5 expressed water demand on a single-family residence basis. This chapter and chapter 246-290 WAC use "ERU" to express the amount of water a single-family residence uses.*

6.4.1 Definition of an Equivalent Residential Unit

An ERU is a water system-specific unit of measure used to express the amount of water consumed by a typical full-time single-family residence (WAC 246-290-010). ERUs are used to equate nonresidential (commercial, industrial, and other nonresidential uses) or multifamily residential water use to the amount used by separate single-family residences. For example, if a water system has sufficient physical capacity to serve 100 ERUs, it has sufficient capability to meet the projected needs of 100 full-time single-family residences. That same water system could also serve any combination of commercial, industrial, and residential customers if the quantity of water used is equivalent to the projected needs of 100 full-time single-family homes (100 ERUs).

Note: *The quantity of water associated with an ERU is water system-specific. The ERU level for one water system may not apply to another water system with differing demographics or water use patterns. The ERU "level of service" for a specific water system may change over time as water use patterns change for various reasons (demographics or water use efficiency activities). Over time, a water system's meter records and changes in demand-level associated with changing water-use patterns, will result in adjustments to the water system's basic ERU level.*

A full-time residence is any single-family dwelling unit that meets two criteria:

1. It houses one or more persons on a regular daily basis for 180 or more days each year.
2. Its occupants regularly use water for indoor use and outdoor irrigation in a manner typical of a single-family household in a residential setting.

6.4.2 Quantity of Water an ERU Represents (ERU-Quantity)

For any calendar year, the quantity of water an ERU represents is expressed in terms of gallons per day per ERU (gpd/ERU). ADD is usually estimated from annual meter records, and MDD is often estimated from daily meter records. See Section 5.2 and Section 5.4 for estimating ADD and MDD in more detail.

Note: *PHD relates to the hydraulic ability of a distribution system to accommodate a range of ERUs. A PHD evaluation determines the physical capacity of the whole water system, not each specific ERU. Table 5-1 identifies the coefficients and factors to use in Equation 5-1. This equation bases PHD determinations on specified ranges of single-family residences. Water use for a typical single-family residence is the same as one ERU. Engineers can use this equation to estimate the peak-hourly flow for the whole water system, or a specific pressure zone, after determining the number of ERUs. Table 5-1 and Equation 5-1, see in Section 6.7.3 and Section 5.2.4.*

Engineers **must** use metered data of sufficient scope and quality to determine ADD and MDD (WAC 246-290-221). For new water systems without metered data, engineers may use comparable water-use data from an acceptable analogous water system or the demand equations in Appendix D to estimate ADD or MDD (also see Chapter 5).

6.4.3 Part-time Versus Full-time Residences

Water demand design data **must** correlate to the number of full-time or part-time equivalent residential units in service at any time (WAC 246-290-221(1)). "Full-time" is a permanent place of residence. "Part-time" is a vacation home, used only seasonally, such as on holidays or weekends. The rule makes this distinction because water systems designed only for part-time residences tend to convert gradually over time to full-time residences (due to retirement, changing housing markets, and other factors).

Water systems designed only for part-time residences cannot be expected to provide service levels adequate for full-time occupancy. Unless obligatory covenants or other binding agreements prohibit full-time occupancy, engineers should consider any part-time residence a full-time residence (one ERU) for design purposes. This concept reduces concerns associated with part-time residents changing to "full-time" without sufficient water supply and delivery facilities. This concept also applies to part-time versus full-time multifamily residences.

Note: *When using meter records to establish the ERU quantity, be sure to account for any part-time uses that occurred during the record-keeping period. Only services that are active during the time of metered data collection should be used. Be sure to confirm the correlation between meter information and the various types of service (residential versus nonresidential) when determining the fundamental single-family residential criteria for a water system. This is particularly important if the available data is only sufficient to estimate ADD.*

6.4.4 Multifamily Residences ERUs

Multifamily residences typically use less water per living unit (dwelling) than separate single-family residences. Water uses for multifamily residences vary from water system to water system. They are usually specific to a given water system, but not always applicable to another water system. When calculating ERUs, engineers should view multifamily usage data apart from single-family usage. To determine how multifamily-metered connections contribute to the water system's overall number of ERUs, divide the total peak-day water use for the multifamily connection(s) by the water system-specific peak-day single-family ERU quantity.

6.4.5 Nonresidential Customer ERUs

To analyze overall demands, engineers can group nonresidential customers by type and select average equivalency factors for each group classification (average ERU per type of nonresidential customer). A nonresidential customer with large water demands (such as agricultural uses, a pulp mill or plating process), should be analyzed separately and included in the ERU totals.

To calculate ERUs for water systems that serve only nonresidential connections, engineers can use the default estimates in Appendix D or comparable water-use data from an analogous nonresidential water system. The ERUs would be the total maximum day demand measured or estimated for nonresidential use, divided by the ERU quantity (gpd/ERU) for MDD (see Section 6.7.1).

6.4.6 ERUs and Distribution System Leakage

Water systems considered municipal water suppliers **must** evaluate distribution system leakage (DSL) (WAC 246-290-820). This leakage **must** be calculated annually (WAC 246-290-820(2)). It should be factored into the capacity analysis also because it exerts demand on the sources, reservoirs, and pump stations of the water system.

Although water systems have used "unaccounted-for water" for many years, there is no standard definition for that term. The WUE requirements use "authorized consumption" and "DSL" to account for all water that passes through the distribution system.

Authorized consumption (AC) is the volume of water **authorized for use** by the water system. Water systems should track and estimate authorized unmetered uses, such as:

- Maintenance flushing of the water system.
- Fire-fighting (hydrant).
- Cleaning water tanks or reservoirs.
- Street cleaning.
- Watering of parks and landscapes.

DSL is all unauthorized uses, water system leakage, and any authorized uses the water system does not estimate or track (WAC 246-290-820(2)).

"Leakage" is the water lost from the distribution system. It includes both apparent losses (theft, meter inaccuracies, and data collection errors) and real losses (reservoir overflows and leaky water mains). Because none of these losses are authorized water uses, they are considered leakage even if they are not actual leaks. Chapter 6 of the *Water Use Efficiency Guidebook* addresses this topic in more detail (WSDOH 2009).

Engineers should calculate DSL in terms of volume <u>and</u> percentage

Volume DSL = TP-AC

Percent DSL = [(TP - AC) / (TP)] x 100%

Where:

DSL = Distribution system leakage (in percentage or gallons)
TP = Total water produced and purchased (in gallons over a specified time period)
AC = Authorized consumption (in gallons over a specified time period)

Section 6.7.5 describes ways to factor DSL into a physical capacity analysis.

6.5 Design Factors

All water system designs **must** meet minimum requirements for all appropriate design elements (source, transmission and distribution, storage, and treatment) (WAC 246-290-200). Engineers **must** determine the water system's overall physical capacity in ERUs based on its most limiting infrastructure feature (WAC 246-290-222). All design factors **must** include minimum reliability requirements and industry standards (chapter 246-290 WAC).

Purveyors, water system customers, or local requirements may establish higher reliability standards, especially for standby storage, which is based primarily on consumer expectations. Local requirements include ordinances, management plans, and critical water supply service areas.

6.5.1 Source

The total daily source capacity, in conjunction with storage designed to accommodate peak use periods, **must** be able to *reliably* provide sufficient water to meet the MDD for the water system (WAC 246-290-222(4)). If sources are not able to meet or exceed PHD, then equalizing storage **must** be provided to meet diurnal demands that exceed source capacity (WAC 246-290-235(2)). Sources **must** also meet minimum reliability requirements (WAC 246-290-420). See Chapter 7 for design guidance for sources.

6.5.2 Transmission and Distribution

A water system **must** be able to *reliably* provide either PHD or maximum day plus fire flow demands, and meet minimum pressure requirements throughout the distribution system (chapter 246-290 WAC). Transmission mains, distribution mains, and booster pump stations **must** meet or exceed minimum reliability requirements (WAC 246-290-420). See Chapter 8 for guidance on mains and Chapter 10 for booster pumps.

6.5.3 Storage

The water system **must** meet minimum operational, equalizing, standby, and fire-suppression storage requirements (chapter 246-290 WAC). The minimum required volume considers the following (WAC 246-290-420):

- The number of sources.
- Source capacity.
- Average-day and peak-hourly demands.
- Local fire-suppression requirements.
- The manner used to achieve reliability requirements (including backup power).

Several demand factors influence the complex relationship between storage and capacity, including ADD, MDD, and PHD. See Chapter 9 for guidance on storage requirements.

6.5.4 Treatment

When water treatment is used, the treatment unit processes **must** be able to reliably supply at least enough water to meet the MDD for the water system while also meeting all water quality performance requirements (WAC 246-290-222(5)). If treatment capacity is not able to meet or exceed PHD, the water system **must** provide equalizing storage (WAC 246-290-235). See Chapter 12 for guidance on water treatment and Chapter 9 for equalizing storage requirements.

6.6 The Relationship between Physical Capacity and Drinking Water Operating Permits

Chapter 246-294 WAC establishes criteria to determine the service adequacy of water systems including the maximum number of allowed service connections (WAC 246-294-040(2)(c)). Section 6.7 presents methodology useful for evaluating a water system's physical capability to meet peak periods of demand. A water system's physical capacity **must** be expressed in ERUs (WAC 246-290-222(2)).

6.7 Methodology to Determine Water System Physical Capacity

The following steps represent an approach for determining a water system's physical capacity. Engineers may use other approaches with adequate documentation and justification.

6.7.1 Step 1: Water Demands

Engineers should determine water demands for residential and nonresidential connections separately, if possible. Residential demand is the amount of water full-time single-family and multifamily residences typically use. Engineers can use the water-use design criteria in Appendix D, or from an analogous water system, only to determine water demand for a new water system.

Information for a water system designed to serve transitory noncommunity populations should indicate the number of nonresidents the water system intends to serve and how many days a year it will provide that service.

Engineers should quantify the following water-demand parameters by using actual water use records, water use from an analogous water system, or the sizing criteria in Appendix D, as applicable:

- $MDD_{(residential)}$ [in gpd/residential connection]
- $ADD_{(residential)}$ [in gpd/residential connection]
- $PHD_{(residential)}$ [in gpm for the water system's residential service population]
- $MDD_{(nonresidential)}$ [in gpd/nonresidential connection]
- $ADD_{(nonresidential)}$ [in gpd/nonresidential connection]
- $PHD_{(nonresidential)}$ [in gpm for the water system's nonresidential service population]

Most often, the design engineer will not be able to obtain daily service meter readings from the various customer classes the water system serves. Most water systems read service meters less frequently. Therefore, engineers will have to develop assumptions and estimates from weekly, monthly, or bi-monthly records to determine the peak-day demand.

Service meter records for some connections may be unavailable or inadequate for engineers to determine separate demands for residential and nonresidential accounts. When that occurs, only source meter information remains to estimate overall demands. When water systems serve mostly single-family residential connections (essentially all of the same type), engineers can use source meter data to reflect the residential demand with reasonable accuracy after adjusting for the estimated distribution system losses. However, when water systems serve a variety of connection types (single-family residential, multifamily, commercial, industrial), the source data will not be sufficient to determine the demand (ERU quantity) of a typical single-family residential customer. Meter data from all nonresidential and multifamily accounts will need to be collected and evaluated. The single-family residential demand can then be determined by calculating the difference between source production and known metered uses.

Lacking specific meter information from the various categories of water system accounts, engineers can assume that single-family residential connections are using all of the water. This will result in a conservative (higher) estimate of the ADD or MDD quantities. With future, more definitive, meter records for nonresidential and multifamily connections, the ADD or MDD can be determined with greater accuracy.

The analysis becomes more complicated when there are many part-time residential water users, nonresidential peaks are highly variable, or there is an unusually large amount of distribution system leakage or unaccounted (but authorized) consumption. Engineers should make the best use of available data and information, and clearly state any assumptions needed to determine actual flow parameters for use in design or capacity determinations. Assumptions may be based on methods using fixture analyses, industrial process-water demand analyses, estimates of crop irrigation requirements, and other approaches. In all cases, DOH expects engineers to document the approach used to include part-time residential, nonresidential and various authorized consumption demands to estimate MDD quantities.

When water demand estimates are made, it is important to start collecting data to validate the estimates and assumptions. A fundamental goal of the engineer and the utility manager should be to improve data-collection efforts so they can get more accurate water-demand estimates for future projects.

6.7.2 Step 2: Source-Based Physical Capacity

All water systems **must** have sufficient source capacity to meet MDD requirements or, in some limited circumstances, source capacity in conjunction with multiple-day storage sufficient to meet peak-demand periods (WAC 246-290-222(4)). You **cannot** include emergency sources in the total source capacity calculations (WAC 246-290-222(3)). Engineers should document the approach they use; data acquired to determine full- and part-time residential, nonresidential, and non-revenue water demands; and how the uses affect the water system’s physical capacity.

Engineers can use the following production records to determine physical source capacity:

- Well (aquifer) capacity.
- Intertie capacity (if used regularly to meet demands).
- Installed pump capacity.
- Treatment capacity.

6.7.2.1 Water Rights

Although water rights place an institutional rather than a physical limit on the amount of water legally available for service, engineers **must** address this important issue. Engineers **must** complete a *Water Rights Self Assessment Form* for all new sources and projects that increase water system physical capacity or the approved number of connections (WAC 246-290-110(4)(e) and 130(4)(a)).

Engineers should contact the Department of Ecology about issues related to water rights. This section recognizes that water rights have a legal bearing on water system capacity determinations. Engineers must consider this limitation because it regulates the amount of water that a water system may withdraw from a source. Engineers may still determine "physical capacity" to be the ultimate capability of a water system's infrastructure to provide certain levels of service, regardless of any legal restraint the Department of Ecology may place on water withdrawals.

6.7.2.2 Well Capacity as Determined by a Pumping Test

A pumping test analysis determines the capacity of the well(s) to reliably supply the water needed to meet service demands. Source capacity **must** be equal to or greater than the water flow needed during peak-use periods. In addition, the total of all sources (except emergency sources), in conjunction with any needed multiple-day storage, **must** equal or exceed the water system's peak-demand periods (WAC 246-290-222(4)).

When evaluating well capacity, the design engineer should consider each of the following:

a. Historical pumping records.
b. Water quality issues.
c. DOH Pumping Test Procedures (Appendix E).
d. Seawater Intrusion (Section 7.1.3).
e. Any storage designed to accommodate peak-use periods.

Engineers **must** provide their analysis of pump-test results to DOH (WAC 246-290-130).

6.7.2.3 Installed Pump Capacity

The installed pump capacity sets the physical upper limit for peak-day water service. Unless storage is designed to meet peak demand periods longer than one day, total peak-day pumping capacity **must** be equal to or greater than MDD for the water system ***(***not including emergency sources) (WAC 246-290-222(4)).

Engineers should consider each of the following when evaluating installed pump capacity:

a. Metered source production and water system demand records.
b. System head conditions when pumping to storage or distribution.
c. Pump curve(s).
d. Pump controls and logic.
e. An engineering analysis that verifies pump performance under actual system head conditions.

6.7.2.4 Interties

Interties with neighboring approved water systems can provide additional source capacity for routine or emergency uses. The engineer should evaluate each intertie to determine its limitations. It is important to consider elements such as hydraulic limitations, water quality, and legal restrictions associated with water rights, or conditions on the purchase contract that define service restrictions. (Section 7.6 provides guidance on interties.)

6.7.2.5 Treatment Capacity

A treatment capacity analysis determines whether any installed treatment processes limit the water system's source production capacity. The water system **must** have sufficient treatment capacity together with storage, to provide a reliable supply of treated water equal to or exceeding the MDD (WAC 246-290-222(5)).

6.7.2.6 Determining ERUs based on Source Capacities

The engineer needs to evaluate the capacity of each individual source a water system uses. The overall water system source-capacity is the sum of the reliable production capability from each source.

The amount of water that any source may provide is the product of its delivery rate and the amount of time it is used for service.

Equation 6-1: Individual Source Capacity

$$Vj = (Qj)(tj)$$

Where:

Vj = Total volume for source "j" over a specified period of time (gallons per specified time period)

Qj = Delivery rate of source (gallons per unit time)

t_j = Time that flow (Q_j) was delivered from source "j" over a specified period of time (minutes, days, or years)

Engineers should base the design flow-rate (Qj) for each source on any limiting factor that might restrict the peak-flow rate (such as well or aquifer capacity, installed pumping capacity, intertie capacity, treatment limitations, or legal limitations).

After determining the source capacity, the engineer can establish the production capability for the water system based on the time that each respective source can be, or is, used within a longer period (over a day, month, or year). For example, a pump may be restricted to operate for only a designated amount of time each day, or a treatment plant may produce water for only certain periods each day. In addition, some sources included in the water system's annual water-demand determinations may operate only seasonally.

Note: *To determine maximum source-production capacity, it is clear that pumping for the full 1,440 minutes a day will provide for the maximum level of service (ERUs). However, even though this allows service for a maximum number of ERUs, it may not be practical to operate source pumps continually for 24 hours, even during peak-demand periods. Whenever there is concern over pump protection under a full 24-hour operation, it may be wise to plan for pump operation less than 1,440 minutes per day. Be sure to factor in any reduced pumping times when determining water system capacity in ERUs.*

When engineers know the specific delivery-rate and operation-time of delivery for <u>each</u> source, they can use Equation 6-2 to determine total source capacity (the total quantity of water available over a specified time period from all sources).

Equation 6-2: Total Source Capacity

$$V_T = \sum(Qj)(tj) = \sum Vj$$ j = individual source designation.

Where:

V_T = Total volume of water available to a water system over a specified period of time, gallons per specified time period

After completing necessary calculations and analyses on all available source capacities, the engineer **must** express water system physical capacity, based on source limitations, in ERUs (WAC 246-290-222(2)(a)).

Engineers can use Equation 6-3 or Equation 6-4 to determine ERUs based on source capacity.

Equation 6-3: ERU based on Annual Average Demand

$$N = \frac{V_a}{(365)(ADD)} = \frac{\sum_{a}^{1}(Q_a)(t_a)}{(365)(ADD)}$$

Where:

N	=	Number of ERUs
V_a	=	<u>Annual</u> volume of water used from all sources, except emergency sources, for the water system (gallons/year)
ADD	=	ADD per ERU, gpd/ERU
Q_a	=	Flow rate of source "a", gpm
t_a	=	Time that source "a" is used per year, minutes/year

Equation 6-4: ERU Based on Maximum Day Demand

$$N = \frac{V_d}{MDD} = \frac{\sum_{d}^{1}(Q_d)(t_d)}{MDD}$$

Where:

N	=	Number of ERUs
Vd	=	Total volume of water used for a MDD for the water system, (gallons/maximum day)
MDD	=	MDD per ERU, gpd/ERU
Q_d	=	Flow rate of source "d", gpm
t_d	=	Time that source operates per day, minutes/day

Note: *Engineers may summarize their source capacity analysis information on Worksheet 6-1 (at the end of this chapter), or a similar form.*

6.7.3 Step 3: Physical Capacity Based on Storage

Chapter 9 specifies minimum storage recommendations for water systems. The particular storage component for each water system includes all of the following:

1. Operational storage (OS).
2. Equalizing storage (ES).
3. Standby storage (SB).
4. Fire suppression storage (FSS).
5. Dead storage (DS), if applicable.

Note: *DS is the amount of water in a storage reservoir used to maintain elevation of the other storage components for pressure considerations in the distribution system. SB, besides what may be in an above-ground tank, may be augmented by approved groundwater wells or interties with other approved water systems that are active, or capable of becoming immediately active, when the need for standby service occurs.*

The total effective storage capacity is based on the amount of stored water needed to meet various demands and includes the ES, SB, and FSS components. Of these, the ES component is important if the source(s) cannot meet PHD (WAC 246-290-235(2)).

Referring to Chapter 9, the engineer should consider each of the following when determining the storage volume requirement:

1. SB that can be augmented through multiple sources (or multiple pumps, if applicable).
2. Applicability of "nested" SB and FSS (check with local fire protection authorities).
3. Adequacy of storage in specific pressure zones.
4. Power grid reliability and adequacy of backup power.
5. Overall water system reliability.
6. Pressure requirements in the distribution system.

OS volume is for pumping and FSS volume is for local fire protection. As such, those storage volumes do not apply directly to routine water demand. Local fire protection ordinances may require water systems to provide FSS that is added to SB storage. Otherwise, OS and FSS may be "nested," which means the larger of the two volumes may be used as the total design requirement for both.

Note: *SB and ES volumes are the only portions of total storage that apply directly to determinations of a water system's physical capacity.*

ES volume is based on PHD demand requirements. SB volume is based on customer concerns or expectations. ES and SB storage design calculations are exclusive of one-another. Storage used for SB cannot be included in ES. In addition, storage for ES cannot be used for SB. Chapter 9 defines customer concerns and discusses ES and SB storage determinations.

ERUs based on Equalizing Storage Requirements
The following relationships apply only to storage reservoirs operated on a "call-on-demand" basis (see Section 9.0.3). Equalizing storage **must** be available at a minimum distribution pressure of 30 psi throughout the water system (WAC 246-290-230(5)).

Applicable Relationships
This section repeats Equation 5-1 and Table 5-1 from Chapter 5 to show how the engineer can determine PHD as a function of residential single-family service. Remember, the amount of water used by one single-family residence is the same as one ERU.

Equation 5-1: Determining Peak Hourly Demand (PHD)

$$PHD = \left(\frac{MDD}{1440}\right)\left[(C)(N) + F\right] + 18$$

Where:

N = Number of ERUs

C = Coefficient associated with ranges of ERUs

F = Factor associated with ranges of ERUs

From Chapter 9, the equation for determining ES is:

ES = (PHD - Qs)(150)

Substituting the general equation for PHD into the equalizing storage equation results in:

Equation 6-5:

$$ES = 150\left[\left(\frac{MDD}{1440}\right)\left[(C)(N) + F\right] + 18 - Qs\right]$$

This equation can be solved for N to give:

Equation 6-6:

$$N = \frac{1}{C}\left[\left(\frac{1440}{MDD}\right)\left(\frac{ES}{150} + Qs - 18\right) - F\right]$$

Where:

MDD = MDD, gpd/ERU

N = Number of ERUs

C = Coefficient associated with ranges of ERUs

F = Factor associated with ranges of ERUs

Qs = Total Source Pumping Capacity, gpm (without emergency sources)

ES = ES, gallons

Table 5-1 (repeated from Chapter 5)

Number of ERUs (N)	**C**	**F**
15 – 50	3.0	0
51 – 100	2.5	25
101 – 250	2.0	75
251 – 500	1.8	125
> 500	1.6	225

Procedure

1. Determine the limitation on ERUs (N) associated with source capacity (Equations 6-3 and 6-4), and the applicable standby storage (Equation 6-5). From these, select the lowest number of ERUs that can be serviced.
2. Using the number of ERUs (N) determined in Step 1, determine (done previously) the MDD value and the total source pumping capacity, Qs.
3. From Table 5-1 select the appropriate values for both C and F for the applicable (estimated) range of N.
4. Solve Equation 6-5 with known values for N, MDD, C, F, and Qs to get the equalizing storage (ES).
5. Subtract all storage complements (OS, SB, FSS, and DS) that are not a part of ES from the total storage available. This is the available ES. **Remember, the water system must maintain a 30-psi pressure in the distribution system when ES is depleted.**

6. If the value from Step 4 is greater than the available ES, then ES becomes limiting (not sufficient ES for the ERU level). You will have to follow Step 7 to calculate the ERUs that the available ES can support.
7. Use Equation 6-6 to determine N (ERUs). This will necessitate a progressive process using values from Table 5-1 for C and F. Use a range of N from Table 5-1 that includes the source-limited ERU level. Using the C and F values for that range, and the previously determined values for MDD, Qs, and ES, calculate N. If the value of N lies outside the range associated with the C and F values selected, repeat the calculation using the next - lower range values for C and F. Continue until the value for N lies within the range of ERU levels associated with the values for C and F selected. That value is the limiting level of ERUs (N) for the amount of equalizing storage available.

ERUs relative to Standby Storage

Equation 6-7:

$$N = \frac{SB_T}{(SB_i)(t_d)}$$

Where:

N = Number of ERUs

SB_T = Total volume of water in standby storage component (gallons) *

SB_i = Design level of standby storage to meet reliability considerations per ERU (gallons per ERU per day)

t_d = Time that storage is to be used (days)

* In some cases, SB is nested within FSS. See Chapter 9 for more detail, particularly when determining credit for multiple sources (or multiple pumps, if applicable).

Engineers may enter tabulated results on Worksheet 6-1, or a similar form.

ERUs relative to the total storage available for a water system

The components of storage are:

Total Storage (TS) = OS + ES + SB + FSS + DS

ES and SB volumes are the only portions of total storage that apply directly to determinations of a water system’s physical capacity. If an engineer knows the total storage (TS) for a water system, subtracts the amounts established for OS, FSS, and DS, the remainder is a combination of ES and SB.

If there are pressure limits associated with ES, engineers can use Equation 6-6 to determine the amount of ES. The SB would then be the amount of water remaining after the OS, ES, FSS, and DS are removed from TS.

If distribution pressure limits do not restrict ES and SB, engineers can determine the physical capacity associated with the combined quantities established for ES and SB as follows:

First, define the capacity-related storage (CRS) as the amount of storage that relates to ERU determinations (ES + SB). Using that with Equation 6-5 and Equation 6-7, leads to the relationship:

$$CRS = ES + SB = 150\left\{\left[\left(\frac{MDD}{1440}\right)\left[(C)(N) + F\right] + 18\right] - Qs\right\} + (SB_i)(t_d)(N)$$

After solving for N, engineers can use Equation 6-8 to determine ERUs when the total storage, or "capacity related" storage (ES + SB), is known and not restricted by distribution system pressure. Of course, engineers also haves to determine the water system parameters for Qs, MDD, F, C, SBi, and td.

Equation 6-8: Determine ERUs when distribution pressure limits do not restrict ES and SB

$$N = \frac{CRS + 150\left[Qs - \left(\frac{MDD}{1440}\right)(F)\right] - 2700}{150\left(\frac{MDD}{1440}\right)(C) + (SB_i)(t_d)}$$

6.7.4 Step 4: Physical Capacity Based on Distribution Facilities

Water system distribution and transmission infrastructure **must** be adequate to accommodate design peak flows (WAC 246-290-230). Distribution adequacy is determined on a pressure zone basis.

Each design parameter below is pertinent to the distribution system capacity determination:

1. Minimum domestic pressure (psig) under normal peak day operating conditions and fire flow, if applicable (WAC 246-290-230 and Section 8.15).
2. Maximum flow velocities (fps) within piping.
3. PHD (gpm).
4. Maximum fire flow requirements (gpm) in combination with MDD (gpd/ERU).
5. Piping sizes (inches in diameter and lengths) and appropriate friction factors.

Engineers should design distribution systems to carry "design levels of flow" to consumers (ERUs) without either unacceptably low pressures or high flow velocities. Engineers use hydraulic analyses to evaluate the distribution-piping network. For very small water systems with few pipes, the analysis is simple, involving hand-held computer calculations. For larger water systems with many pipes or pressure zones, the analysis can be complex, requiring computer simulations.

The engineer must estimate the flow needed to provide a level of service under peak-demand conditions for any portion of the piping network, and then determine the piping size necessary to provide design flows while maintaining adequate pressures for customer service in all pressure zones. If the analyses show the proposed water system cannot meet design flow with a designated piping size, the engineer must adjust the piping size or physical capacity will be limited. Procedures for performing hydraulic analyses are in engineering academic curricula, textbooks, and other publications available to the profession.

Designing the distribution system and storage facilities to accommodate fire flow is important. However, pipe and reservoir sizing requirements are not based on an ability to provide peak-day or peak-hour levels of water service to the water system's consumers. Rather, the fire flow requirements come from local fire authorities. The flow rates and length of time to maintain them are established to provide capacity for local fire fighting. They are not related to the water system's physical capacity. Physical capacity is based solely on the hydraulic ability of the water system to meet the PHD. Usually, a water system designed to meet fire flow requirements can also meet the PHD-based flow requirements.

DOH recommends that engineers determine the physical capacity of a proposed water system's supply sources or storage before analyzing the distribution network to determine hydraulic restrictions on physical capacity. Pay attention to larger service demands in specific areas of the network, such as fire flows, industrial or commercial needs, and water system expansions proposed to serve significant development. For example, a large subdivision that would require extended service lines. When engineers find limits on the number of ERUs within the distribution system, they should install larger piping or acknowledge the limitations on the level of ERU service the water system can accommodate.

6.7.5 Step 5: ERUs Based on Distribution System Leakage

A water system's physical capacity is based on its total source capability (production). Water system production "lost" through DSL is no longer available for customer service. As such, DSL reduces a water system's ability to serve customers. A water system can increase its ability to serve more customers by:

- Adding sources (and maybe storage and distribution system improvements to meet peak demands).
- Reducing DSL.
- Reducing customer demand.

Some DSL will occur, even in very well maintained and managed water systems. For most water systems, it is impractical to eliminate all DSL (AWWA 2006).

For water systems, several factors influence the real water losses that are part of DSL including:

- Number of service connections.
- Length of water mains.
- Average operating pressure.
- Infrastructure condition (Thornton 2002; AWWA 2006).

Because these factors are independent of demand, DSL is more likely to be consistent on a volume basis than on a percentage basis throughout a year. Engineers can use the annual average volume of DSL and divide by the number of days in the year to identify a daily volume of DSL.

That said, unless the water system estimates or meters authorized uses (such as publicly owned facilities, parks, playgrounds, or main flushing), there will be seasonal fluctuations in DSL due to inaccurate accounting. If there is good information to adjust the DSL as part of a physical capacity analysis, it should be used.

After you estimate the daily volume of DSL, there are several ways you can use DSL in the physical capacity analysis of a water system.

- Spread out DSL equally among all customers on an ERU or connection basis.
- Express DSL as a separate demand on the water system.
- Express DSL in terms of ERUs.

You should clearly document the approach used to factor DSL into the physical capacity analysis along with any related assumptions.

6.7.6 Step 6: Determine Limiting Criteria and Water System Physical Capacity in ERUs Capable of Being Served

Worksheet 6-1 may be useful for summarizing the features that limit the total ERU complement of a water system. In summary form, this information would be useful for indicating to purveyors the elements of the water system they need to address to increase capacity of their water systems.

Table 6-1 summarizes the equations used in sections 6.7.2 and 6.7.3 to determine ERUs for a water system based on source- or storage-capacity. This table indicates the equation for ERUs (termed "N") that apply when certain information relative to an ERU calculation is available.

References

AWWA. 2006. *Water Conservation Programs – A Planning Manual*. AWWA Manual M52. American Water Works Association, Denver, CO.

Thornton, J. 2002. *Water Loss Control Manual*. McGraw-Hill, New York, NY.

WSDOH. 2009. *Water Use Efficiency Guidebook*, DOH 331-375, Washington State Department of Health, Olympia, WA.

WORKSHEET 6-1: ERU Determinations

Water System Physical Capacity Documentation based on MDD

Note: *Capacity determinations are only for existing facilities that are operational for the water system.*

Specific Single-Family Residential Connection Criteria (measured or estimated demands) (see Chapter 5):

Average Day Demand (ADD): __________________ gpd/ERU

Maximum Day Demand (MDD) __________________ gpd/ERU

Water System Service Connections correlated to ERUs			
Service Classification	**Total MDD for the classification, gpd**	**Total # Connections in the classification**	**ERUs**
Residential			
Single-family			
Multifamily			
Nonresidential			
Industrial			
Commercial			
Governmental			
Agricultural			
Recreational			
Other (specify)			
DSL		N/A	
Other (identify)			
Total existing ERUs (Residential + Nonresidential + Non-revenue + Other) =			_______________

Physical Capacity as ERUs	
Water System Component (Facility)	**Calculated Capacity in ERUs for each component**
Source(s)	
Treatment	
Equalizing Storage	
Standby Storage	
Distribution	
Transmission	
Other (specify)	
Water System Physical Capacity (ERUs) = **(based on the limiting water system component shown above)**	

Note: *If multiple-day storage is needed to meet MDD, another approach to estimate the ERU capacity is necessary.*

Table 6-1: Determination of Equivalent Residential Units (ERUs)

Available Information (what is known)	ERU Equation (Determination of N)*
Source Capacity (Annual Average) Based 1. Average rate of flow for each source. 2. Time each source operation annually. 3. ADD for the water system. 4. Average annual volume of water used.	**Equation 6-3**: $N = \frac{V_a}{(365)(ADD)} = \frac{\sum_{a}^{1}(Qa)(ta)}{(365)(ADD)}$
Source Capacity (Peak Day) Based 1. Flow rate of each source on peak day. 2. Time each source operates on peak day. 3. MDD for the water system. 4. Total volume of a peak day demand.	**Equation 6-4:** $N = \frac{V_d}{MDD} = \frac{\sum_{d}^{1}(Q_d)(t_d)}{MDD}$
Equalizing Storage Capacity Based 1. MDD for water system. 2. ES available at 30 psi minimum. 3. Total source pumping capacity. 4. PHD equation factors, C and F.	**Equation 6-6**: $N = \frac{1}{C}\left[\left(\frac{1440}{MDD}\right)\left(\frac{ES}{150} + Qs - 18\right) - F\right]$
Standby Storage Based 1. Total available SB storage. 2. SB desired per unit. 3. Duration that SB is expected to be used.	**Equation 6-7**: $N = \frac{SB_T}{(SB_i)(t_d)}$
Total "Capacity-Related Storage" Based 1. ES available at 30 psi. 2. SB desired, available for water system. 3. Duration of SB when needed. 4. PHD equation factors, C and F.	**Equation 6-8**: $N = \frac{CRS + 150\left[Qs - \left(\frac{MDD}{1440}\right)(F)\right] - 2700}{150\left(\frac{MDD}{1440}\right)(C) + (SB_i)(t_d)}$

* See the descriptions of thee equations in Chapter 6 for definitions of the terms above.

Chapter 7: Source of Supply

A water system **must** have sufficient source capacity to meet customer demand (WAC 246-290-222(4)) and provide reliable service (WAC 246-290-420). DOH also **requires** the source to provide the highest quality drinking water feasible (WAC 246-290-130(1)).

7.0 Water Resource Analysis and Water Rights

With available technology, it is possible to design a treatment plant to produce high quality drinking water from just about any water source. However, rather than water quality, the true feasibility of using a source may depend on political, economic, and legal considerations or the availability of qualified operations and management staff. The factor that could affect a given source the most is the legality of the water withdrawal. Therefore, as part of the source approval process, the engineer **must** do a water resource analysis to consider and address water rights issues (WAC 246-290-130(3)).

7.0.1 Water Resource Analysis

A water resource analysis **must** evaluate opportunities to obtain or optimize the use of sources already developed, or other methods to meet water needs (WAC 246-290-100 (4)(f) and 110(4)(c)). DOH expects the evaluation to include:

- Enhanced water use efficiency measures
- Water right changes
- Interties
- Artificial recharge
- Use of reclaimed water
- Reuse and other nonpotable sources
- Treatment of existing sources

There is significant health risk associated with improperly treated surface water. Therefore, DOH expects purveyors to conduct a comprehensive comparison of the alternatives before developing a new surface water supply. See Section 2.2.3 for further discussion of alternative analysis.

Surface water supplies **must** receive complete treatment (typically filtration and disinfection) (WAC 246-290-250(2) and 601(1)). See Chapter 4 of the *Water System Planning Handbook* (DOH 331-068) for further guidance on water resources analysis.

7.0.2 Water Rights

Water supplies for Group A water systems **must** conform to state water right laws (WAC 246-290-130(3)(b) and (4)(a)).

Water systems that submit new source development or other growth-related projects for DOH review and approval (WAC 246-290-100(4) or 110(4)(e)) **must** include a *Water Rights Self-Assessment Form* (WAC 246-290-130(4)(a)). DOH uses this form to ensure the water system has adequate water rights to meet the projected increased ability to provide service. The form is available on the DOH Web site (see Appendix A).

Note: *Water systems that develop new water supply sources beyond the regulatory thresholds of chapter 90.44 RCW* ***must*** *have a water right permit from the Department of Ecology.*

7.1 Source Water Quantity

The source or sources for a water system **must** be able to meet the water system's maximum day demand (MDD) (WAC 246-290-222(4)). In rare cases, DOH may grant an exception to this requirement if a water system has multiple days of storage to provide peak-day service when the supply sources cannot meet the MDD on their own. For reliability purposes, supply sources should be able to replenish depleted fire suppression storage within 72 hours while concurrently supplying the MDD of the water system.

7.1.1 Demonstrating Source Capacity

Sources **must** be able to reliably meet projected demands (WAC 246-290-130(3)(c)). Largely, this ability depends on the type of water source proposed.

For example, surface water sources depend entirely on climatic influences from year to year and spring sources depend on precipitation levels in their recharge areas. Engineers can use flow measurements and hydrologic assessments with an appropriate factor of safety to measure spring or surface water capacity. However, when defining expectations for long-term service, engineers should base the reliability of flow from these sources on years with the lowest precipitation levels.

Groundwater is less dependent on annual weather conditions, except for some areas where localized recharge "lenses" occur. Engineers can use pump tests to estimate how well groundwater can meet the demands of a projected population over time (well capacity).

A utility should know how likely it is that a particular surface or spring source will sustain adequate service in low rainfall years and plan for levels of adequacy commensurate with customer expectations. This is difficult to do. Water systems should correlate historic hydrographic flow models against customer expectations for service. What probability of periodically curtailing service, either voluntary or mandatory, is acceptable to the service population? Once every 10 years, 20 years, 50 years? Engineers should understand this concept and be able to make the utility understand how important long-term water demand projections are for development.

7.1.2 Seawater Intrusion

Wells or well fields developed close to seawater may be vulnerable to seawater intrusion. DOH recommends that water systems have a hydrogeologist or qualified engineer assess the potential for seawater intrusion and oversee well testing. See Appendix E for guidance on developing sources vulnerable to seawater intrusion. Wells are at risk for intrusion if they are:

- Within ½ mile of the shoreline and pump water from a depth below sea level.
- Within ½ mile of a groundwater source with chloride concentrations over 100 mg/L.

The design engineer should avoid supply sources at risk for seawater intrusion. The Department of Ecology may condition water right permits to provide for reduced pumping rates or even require a water system to abandon sources if seawater intrusion threatens senior water right permits. In addition, several counties have policies or ordinances affecting water systems in areas vulnerable to seawater intrusion. DOH recommends that the design engineer contact the Department of Ecology and the local health jurisdiction for current policies or rules on developing wells where seawater intrusion may be a concern.

7.2 Source Water Quality and Protection

All sources used for water service **must** meet water quality standards, known as maximum contaminant levels (MCLs), set by EPA or the state (WAC 246-290-310). Water systems **must** treat sources as required to meet water quality standards (WAC 246-290-130(5), 250, and Part 6).

Sources **must** have sample taps to meet the water quality monitoring requirements of WAC 246-290-300. In most cases, sample taps are required:

- **From the source, prior to any treatment.** Install the sample tap as close to the source as practical.
- **After treatment, before entering the distribution system.** If there are multiple treatment processes, install sample taps after each unit process.

The sample tap should be smooth-nosed, without internal or external threads (Ten State Standards 2007). Sampling requirements for reservoirs and distribution systems are in Chapters 8 and 9 and WAC 246-290-300.

7.2.1 Primary Contaminants

The water from sources **must** meet minimum water quality standards prior to use (WAC 246-290-130(3)(g)). The minimum initial water quality testing varies by:

- Type of water system.
- Location within the state.
- Type of source (groundwater or surface water).
- Susceptibility of the source to contamination.

The minimum initial required source water quality testing includes analyzing for:

- **Bacteriological safety:** For most groundwater sources, one coliform sample is required. DOH may require additional bacteriological sampling for some groundwater sources and all surface water sources prior to, or as a condition of, source approval.
- **Inorganic chemicals (IOCs) and physical parameters:** DOH requires a complete IOC sample for all new sources.
- **Volatile organic chemicals (VOCs):** DOH requires a complete VOC sample for all new sources. DOH may require additional sampling if a chemical is detected in the initial sample.
- **Radionuclides:** DOH requires a sample for Gross Alpha and Radium 228 only for sources serving community water systems.
- **Synthetic organic chemicals (SOCs) and Ethylene Dibromide (EDB):** DOH requires sampling only for vulnerable sources in certain parts of the state. These are usually in agricultural areas, where SOCs and EDB were used. DOH staff will inform the water system if SOC or EDB sampling is required for source approval.

If a primary contaminant is measured at a concentration above its MCL, treatment **must** be installed and tested before the source is used (WAC 246-290-130(3)(g)). Contaminants detected at concentrations less than the MCL may trigger additional source water quality testing. The frequency of follow-up testing depends on the contaminant and its concentration. For example, the threshold for additional nitrate sampling is one-half its MCL, while the threshold for additional VOC sampling is 0.0005 mg/L.

The design engineer should be sure that any low levels of organic contaminants are not residuals from construction or source development. Generally, if testing reveals VOCs in a water sample from a new well, the well should be cleaned, purged, and re-tested.

7.2.2 Secondary Contaminants

Secondary contaminants, such as iron and manganese, are regulated for aesthetic reasons such as adverse taste and odor, or staining plumbing fixtures. In general, source(s) **must** meet the water quality standards of WAC 246-290-310. New community and nontransient, noncommunity water systems without active customers **must** treat if secondary contaminants exceed the MCL (WAC 246-290-320(3)(d)). However, existing water systems may install treatment consistent with the degree of consumer acceptance of the water quality and their willingness to bear the costs of meeting the secondary standard. See Appendix B for additional guidance on secondary contaminants.

Note: *Consider treatment by sequestering only if the combined iron and manganese levels don't exceed a total of 1.0 milligrams per liter (mg/L), with the manganese level being no more than 0.1 mg/L.*

7.2.3 Groundwater Under the Direct Influence of Surface Water

Groundwater under the direct influence of surface water (GWI) is any water beneath the surface of the ground with:

1. Significant occurrence of insects or other macroorganisms, algae or large diameter pathogens such as *Giardia lamblia*, or
2. Significant and relatively rapid shifts in water characteristics such as turbidity, temperature, conductivity, or pH, which closely correlate to climatological or surface water conditions (WAC 246-290-010).

Purveyors with sources confirmed to be GWI **must** comply with the filtration and disinfection requirements for surface water sources (WAC 246-290, Part 6).

Purveyors **must** evaluate all potential GWI sources to determine if additional treatment is necessary (WAC 246-290-640). Potential GWI sources include:

- Wells that withdraw water from less than 50 feet below the ground surface and are located within 200 feet of surface water.
- Infiltration galleries.
- Ranney wells.
- Springs.

DOH will not approve a new potential GWI source before a proper evaluation. Figure 7-1, at the end of this chapter outlines the evaluation process for potential GWI sources.

Potential GWI sources *not* confirmed to be GWI are *not* required to meet the treatment requirements for surface water sources. However, potential GWI sources that are in *hydraulic connection* with surface water **must** provide adequate disinfection prior to distribution (WAC 246-290-640(4)). Additional guidance on evaluating potential GWI sources is available from references at the end of this chapter (WSDOH 2003a; WSDOH 2003b).

7.2.4 Blending Dissimilar Waters

Water systems **must** review how proposed projects could potentially affect water quality (WAC 246-290-110(4)(d)). Blending a new source with existing sources or replacing existing sources with new ones can create water quality problems in the distribution system (Taylor et al. 2005; Kippin et al. 2001). For example, iron or manganese can precipitate when surface water with higher dissolved oxygen levels is blended with groundwater. Water systems **must** specifically address how a new source will affect compliance with the Lead and Copper Rule (40 CFR 141.90).

7.2.5 Source Protection

Water systems **must** maintain a sanitary control area around each source to protect against existing or potential sources of contamination (WAC 246-290-135(2)). A susceptibility assessment is **required** as part of a wellhead protection program (WAC 246-290-135(3)). Water systems with surface or GWI sources **must** develop and implement a watershed control program (WAC 246-290-135(4)).

7.2.6 Rainwater Collection Systems

In Washington, there is less rainfall during the summer, which is the period of greatest water demand for most water systems. The engineer will have to evaluate rainfall, usage patterns, and water storage thoroughly to ensure a reliable supply. In addition, surface water withdrawals, including rooftop catchments, may be subject to water rights regulations. The engineer should contact the Department of Ecology early in the design process for guidance on water rights permitting.

Rainwater collection (rooftop collection) systems are frequently considered when there are water resource limitations and for ecological reasons, such as a desire to decrease storm water runoff. With adequate safeguards to protect public health, these systems can supply both potable and nonpotable uses.

Rainwater is considered a surface water source. As such, any drinking water system that uses collected rainwater **must** provide treatment, including filtration and disinfection. Design considerations, ongoing operations and maintenance requirements, and daily monitoring and monthly reporting are in WAC 246-290, Part 6.

Rainwater is slightly acidic and low in dissolved minerals. These qualities make it corrosive to metals and other materials. The rooftop collection material and coating systems **must** meet ANSI/NSF Standard 61 to reduce the risk of chemical contaminants entering the untreated water. In addition, the purveyor may have to adjust the finished water quality to make it less corrosive.

Rainwater collection systems intended for nonpotable uses are a high cross-connection control hazard, especially if the rainwater system is pressurized or has internal plumbing. Therefore, any water system providing service to a building with a rainwater collection system **must** protect the water distribution system from possible cross connections (WAC 246-290-490).

7.2.7 Desalination

Desalination of seawater or brackish groundwater is technically feasible and may be the only option available in some situations. Engineers should consult with DOH before initiating a desalination project. DOH will focus its concerns on water quality and aesthetic problems. Engineers should contact other county, state, and federal agencies early in the design process to identify potential permitting issues. See Chapter 12 and Appendix G for issues associated with brackish water and seawater desalination.

7.3 Groundwater Sources (Wells)

Groundwater is the most common form of drinking water supply in Washington State. The vast majority of source development projects in the state are drilled wells and well fields (see the *Well Field Designation Guideline* in Appendix B). The approval of such projects is an important DOH function. The process and documentation for approval of wells is explicit and detailed. See Appendix F for guidance on preparing a project report or the construction documents for a new well. See Appendix F and Chapter 4 for details on the approval process. See Appendix E for guidance on pumping tests for wells.

The engineer can use a pump test or hydrogeological analysis to determine how reliable groundwater or aquifers will be over time. DOH expects pumping tests to run at a flow rate greater than or equal to the maximum design pumping rate (WAC 246-290-130(3)(c)(iii)). However, purveyors may use well source development data from other sources to demonstrate that water quantity is adequate to meet design criteria. In standard aquifer settings, if hydrogeological information is adequate to establish a sustainable pumping rate, the engineer may submit a hydrogeological report to justify the proposed pumping rate. In this case, the purveyor should expect both the DOH regional engineer and a DOH hydrogeologist to review the justification.

Pumping Tests

The objective of the pumping test is to get data to support the source's ability to reliably provide a safe yield at the maximum design rate and to size the well pump and establish a depth setting. Specific reliability concerns include low-flow conditions, fracture-flow conditions, aquifer of limited areal extent, seawater intrusion, affects of concurrently pumping multiple wells, and seasonal variability.

The design engineer must ensure the pumping test provides sufficient data to achieve its objectives. See Appendix E for detailed guidance on pumping tests.

After the pumping test, compile the following data into a project report, and submit it to DOH:

a. All items for source approval, if applicable (see Appendix F).
b. A time-drawdown graph (on standard and semi-log paper).
c. An analysis and discussion of applicable hydraulic parameters (such as transmissivity, hydraulic conductivity, storativity), *as appropriate*, to support the objectives of the pumping test.
d. A map and description (1/4, 1/4, section, township, range) accurately indicating the well location and the land surface elevation to the nearest foot. Locate observation wells with distances to the nearest foot.
e. A well report.
f. A copy of lab test results.

7.4 Spring Sources

Purveyors may only develop a spring source if:

- It can provide a reliable quantity of flow for all intended demands throughout the year.
- They protect the sanitary quality of the spring water from contamination at all times.
- They sufficiently test to ensure adequate initial water quality before it is used.

Because springs are potential GWI sources, purveyors **must** confirm the GWI status of the spring (WAC 246-290-640). DOH expects the content of the project report for a spring source to comply with the elements of Section 7.3 or 7.5. Requirements depend on the GWI determination.

The project report for a spring **must** address the safe, reliable yield required to meet service demands (WAC 246-290-222(4) and 420). Methods for determining the quantity and reliability of a spring's flows are not always easy to apply, or interpret. Pumping test procedures do not particularly apply to springs because the recharge is unidirectional and associated only with the delivery of flow at the ground-surface interface. Therefore, to measure spring-flow quantity, purveyors should use actual flow records (with weirs or other mechanisms capable of measuring surface flows).

Because seasonal fluctuations or drought conditions often affect spring flows, it is appropriate to estimate the flows that would prevail in the driest years. Drought conditions are periods in which rainfall is consistently below annual averages. DOH recommends that purveyors use the 20-year low-rainfall level as the baseline for estimating available, reliable flows. Spring flows are inherently uncertain, so it also is appropriate to apply a safety factor to any flow quantity derived from measurements. DOH considers a factor of no more than one-half the measured flow appropriate for estimating the design flow of a spring source to be used for water service.

In general, unique geological conditions will dictate the steps engineers will follow when developing a spring source. Engineers should tailor their design and construction activities to protect the spring, and the areas above the spring, from surface contamination.

- Construction materials **must not** create an opportunity for water quality problems (WAC 246-290-220).
- Surface water runoff diversions should be provided.
- Designs for spring collectors and catchment facilities must prevent infiltration of contamination.
- Protection from vandalism should be instituted (fencing, lockable hatches, and other security measures).
- Requirements for screening vents or other openings appropriate to the spring are similar to those for distribution reservoirs (see WAC 246-290-235).

The design engineer can get guidance and specific details on spring development, sanitary protection, and water quality considerations in the references listed at the end of this chapter (AWWA 1999; USEPA 1991).

7.5 New Surface Water Supplies

Surface water supplies normally require treatment by conventional, direct, slow sand, diatomaceous earth filtration, or an approved alternative technology and **must** comply with the Surface Water Treatment Rule and WAC 246-290, Part 6. Detailed design criteria are in WAC 246-290, the *Surface Water Treatment Rule Guidance Manual* (DOH 331-085), and Chapter 12. In some cases, engineers may need DOH to approve the intake facilities before initiating the pilot study.

Engineers can help to ensure an efficient and orderly review of their surface water treatment proposals by meeting with staff at the appropriate DOH regional office (see Table 1-1) to establish specific design requirements.

In addition to treatment, the design engineer should consider the unique features of surface sources when evaluating them for the drinking water supply. Often, several competing beneficial uses (agriculture, fisheries, and other resource demands) affect the long-term reliability of surface sources. Water rights may be very difficult to secure, and they may be so restricted during some periods that only a small portion of the source can be used to supply drinking water. The reliability of this type of source is inherently subject to greater degrees of uncertainty because of its association with annual precipitation levels (rain and snow).

Purveyors should develop surface sources with full knowledge that some reductions in service capacity may result over time as low rainfall years, low snow-pack years, or drought conditions occur. Purveyors will need to compare historic hydrological data against customer service expectations to gauge the adequacy of the source. (How acceptable would it be to your customers if you had to curtail water service once every 10 years, 20 years, or 50 years?)

7.6 Interties

Interconnections (interties) between water systems are an alternative to developing new supply sources. They can help ensure levels of reliability that would be difficult to secure otherwise. Water conveyed through an intertie may need to meet criteria for water right changes, and may require treatment. RCW 90.03.383 addresses intertie approvals intended to resolve emergent public health concerns, short-term emergencies, and drought emergencies.

A water system considering an intertie to augment supply sources **must** meet the requirements of WAC 246-290-132. For guidance, see the *Water System Planning Handbook* (DOH 331-068).

7.7 General Reliability Considerations (power outages and equipment failures)

In addition to a source's ability to meet the design demands of a water system over time (see Section 7.1.1), reliability includes (1) the ability of the engineered facilities to meet the designed performance criteria for the water system, and (2) the legal authority to use the water over time.

Purveyors should protect all water supply sources, to the extent possible and prudent, against power loss and potential water system depressurization. DOH highly recommends on-site backup power equipment or gravity standby storage unless the purveyor can document that the power grid meets the minimum reliability criteria defined below:

1. Outages average three or less per year based on data for the three previous years with no more than six outages in a single year. Power loss for at least 30 minutes usually qualifies as an outage.
2. Outage duration averages less than four hours based on data for the three previous years, with no more than one outage during the three previous year period exceeding eight hours.

Regardless of the power grid reliability, purveyors **must** consider the possibility for water system depressurization during power outages or other source-related failures that may cause cross-connection problems. The reliability standards established in WAC 246-290-420 **must** remain a predominate consideration.

Note: *All water systems should conduct a water system risk and reliability assessment. They should design to a standard that meets customer's reasonable expectations, and avoids cross-connection control problems*.

7.8 General Source Considerations

DOH considers several elements associated with new or existing drinking water sources when reviewing design documents and subsequent reports.

7.8.1 Groundwater with High Initial Turbidity

Initial samples often reveal high turbidity in new wells. Purveyors should thoroughly purge and pump wells to remove construction residuals. Turbidity may indicate groundwater under the influence of surface water, excessive levels of iron or manganese, or a need for filtration. Turbidity can interfere with disinfection, and cause distribution-related problems and customer complaints. Turbidity in groundwater is a significant concern, particularly turbidity with no reasonable or logical explanation. The engineer should get additional guidance from the appropriate DOH regional office (see Table 1-1).

7.8.2 Drilling Fluids and Well Contamination

It is possible to introduce bacterial or organic contaminants (tetrahydrofuran, toluene, 2-butanone) during well construction. Therefore, purveyors should properly disinfect and purge new sources before collecting samples for water quality testing.

7.8.3 Criteria for Multiple Sources or Multiple Pumps per Source

DOH encourages water systems to have multiple supply sources. These sources may offset recommended standby storage (SB) volumes.

DOH recognizes that multiple pumps for a single source may be more reliable than a single-pump source. However, we do not consider a single source with multiple-pumps to be as reliable as multiple sources. The following criteria apply to "multiple pumps in a single source" when evaluating any reduction in SB volumes (see Section 9.0.4(2)).

1. If the pumps are in a large capacity, large diameter well such that each pump can be taken out of service, and replaced or repaired without the need to interrupt operation of the other pump(s), DOH *may* consider the installation *equivalent to* independent sources. There should not be any significant reliability issues that independent sources would better address (imminent threat of groundwater contamination, and high transmission main vulnerability). Furthermore, the well design should include controls to detect a pump failure, an auto-switch to a good pump, and an auto dialer to indicate the pump has failed.
2. Multiple pumps in one well that can only be repaired or replaced by taking the source out of service may ***not*** be considered *equivalent to* multiple sources. This type of installation *may still allow* reduced SB volumes if the purveyor includes a plan to address repairs and minimize downtime in the operations program for the water system (WAC 246-290-415).

In either situation, the well(s) should be easy to access for repairs and pump removal. Purveyors should consider a service contract with a qualified repair or service entity, when appropriate, to meet customer expectations for service.

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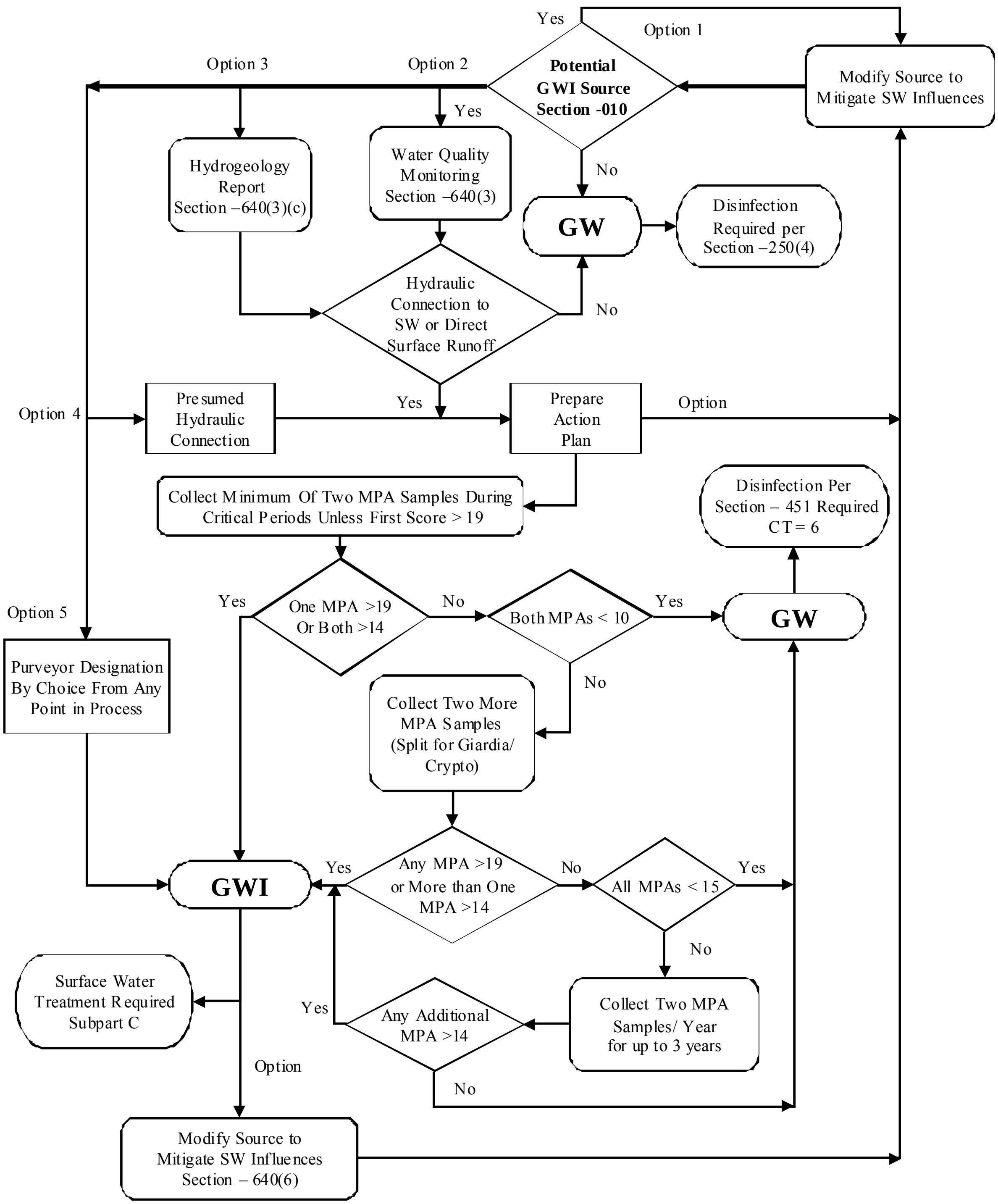
Acronym Key for Figure 7-1

CT	Chlorine Concentration x Time
GW	Groundwater
GWI	Groundwater under the direct influence of surface water
MPA	Microscopic Particulate Analysis
SW	Surface water

Figure 7-1 Evaluating Potential GWI Sources WAC 246-290-640



Chapter 8: Transmission and Distribution Main Design

Transmission and distribution mains represent most of the initial cost of a water system. These system components are not visible when construction is complete. Therefore, good design and construction are vital if a water system is to deliver safe, adequate, reliable water as economically as possible. This chapter provides guidance on the size, materials, facility location, and other design factors required to meet customer demands in the service area.

8.0 Transmission and Distribution Main Definitions

Transmission mains convey water from the source, treatment, or storage facilities to the distribution system. There *may* be a few service connections on the transmission main, but the purpose of this larger diameter pipe is to deliver water to the distribution mains where most of the service connections are.

Distribution mains deliver water to individual customer service lines and provide water for fire protection through fire hydrants, if applicable.

8.1 Facility Sizing

When sizing water system mains, engineers should consider many factors including pumping costs, water system demand, land use, friction losses, and flow velocities. These factors interrelate, so designers should recognize the influence of each when selecting optimum piping arrangements. Engineers **must** design transmission lines, distribution facilities, water sources, pumping facilities and storage facilities so that, together, they meet minimum demand and pressure requirements throughout the distribution system (WAC 246-290-230).

8.1.1 Sizing Procedures

Many engineering textbooks, reference books, and design manuals convey procedures for sizing water system distribution and transmission lines. There also are many common computer programs available to aid in the design of complex water systems. DOH expects engineers to use design procedures consistent with those the professional civil engineering discipline applies and accepts as good engineering practice.

8.1.2 Minimum Size

Engineers **must** use a hydraulic analysis to determine the minimum size of a transmission or distribution main (WAC 246-290-230(1) and (9)). The hydraulic analysis must address the parameters outlined in Section 8.2. In general, the main sizes must be able to provide the flow rates required to serve the anticipated land use near the water system as characterized in the water system plan and the local land use plan. All distribution mains **must** be at least 6 inches in diameter, unless a hydraulic analysis justifies another size (WAC 246-290-230(2)).

Any pipeline designed to provide fire flow **must** be at least 6 inches in diameter (WAC 246-290-230(3)). Minimum fire flow requirements are in the Water System Coordination Act (WAC 246-293-640). Counties and local fire protection authorities often have more stringent fire flow standards than these minimum requirements.

Engineers **must** consider at least two demand scenarios when using a hydraulic analysis to size mains (WAC 246-290-230(5) and (6)).

- **First**, the water system **must** be able to deliver the peak hourly demand at the required pressure of 30 psi at every existing and proposed service connection.
- **Second**, if the water system provides fire flow, the distribution pipelines **must** be able to deliver the maximum day demand (MDD) rate, in addition to the fire flow, at the required pressure of 20 psi throughout the distribution system.

There is more detail on this analysis in sections 8.1.5 and 8.2.3l.

8.1.3 Peak Hourly Demand

Distribution pipelines **must** be able to deliver enough water to meet peak hourly demand (PHD) at 30 psi at every existing and proposed service (WAC 246-290-230(5)). PHD is the maximum rate of water use expected to occur in a defined service area over a continuous 60-minute period, excluding fire flow. Unless there are accurate water demand records identifying PHD, the designer should use the equations in Chapter 5 to determine PHD. If there is more than one pressure zone, the engineer must calculate PHD separately for each zone.

Note: *Prior to 1999, DOH design guidelines called PHD "maximum instantaneous demand."*

8.1.4 Fire "Suppression" Flow

In most cases, the local fire protection authority determines fire flow rate and duration requirements for water systems. If the local government does not establish minimum fire flow standards, the engineer **must** use the standards in the Water System Coordination Act (WAC 246-293-640). These fire flow standards apply to new or expanding water systems:

- Within the boundaries of a designated Critical Water Supply Service Area.
- With more than 1,000 services (WAC 246-293-602 and WAC 246-290-221(5)).

Typically, the fire protection authority is the town or city fire chief, or county fire marshal in unincorporated areas. Some incorporated areas may contract for fire protection services with a district or the county.

In addition to protecting public safety, a water system's ability to provide fire flow is important because it is one of the main criteria used to establish the insurance rating for that fire district or city.

The insurance industry uses a national rating system to estimate relative fire risk and set local insurance rates (1 is very good, 10 is very bad). Fire insurance premiums are lower for businesses and homeowners in fire protection districts and municipalities that earn better ratings.

In our state, the Washington Surveying and Rating Bureau administers this rating system. The bureau bases the rating system criteria distributed among four key components:

1. 10 percent is the “9-1-1” center’s ability to answer and dispatch calls.
2. 10 percent is the level of fire code enforcement.
3. 40 percent is the fire department, itself.
4. 40 percent is the reliability of the water system and its ability to provide required fire flows.

8.1.5 Minimum Distribution System Pressure

The water system **must** be able to provide PHD at no less than 30 psi at all service connections throughout the distribution system when all equalizing storage is depleted (WAC 246-290-230(5)). The water system **must** meet this minimum pressure at all existing and proposed service water meters or along property lines adjacent to mains if no meters exist. The water system does not have to meet 30-psi minimum pressure during fire-flow conditions.

During fire suppression events, the water system **must** be able to provide 20-psi minimum pressure at ground level at all points throughout the distribution system. The water system **must** be able to provide this minimum pressure under fire-flow conditions plus the MDD rate when all equalizing and fire flow storage is depleted (WAC 246-290-230(6)). Engineers **must** design transmission mains with no service connections to maintain pressure of 5 psi or more, unless the mains are directly adjacent to the storage tanks (WAC 246-290-230(9)).

DOH allows water systems to use individual-service booster pumps as an interim solution to provide minimum design pressure, but they are not acceptable as a permanent design feature. See Chapter 10 for specific design guidelines on individual-service booster pump stations.

8.1.6 Maximum Velocity

DOH recommends a maximum velocity of no more than 8-feet per second (fps) under PHD conditions, unless the pipe manufacturer specifies otherwise. Maximum velocities greater than 8 fps may occur under fire flow conditions, for short main sections, or piping in pump and valve station facilities. Engineers should conduct a hydraulic transient (water hammer) analysis for distribution piping designed to exceed 10 fps during PHD or fire flow conditions (Walski et al. 2003; AWWA 2004). See Section 8.1.8 for a discussion on surge control and Section 8.2.4 for modeling transient conditions.

8.1.7 Excess Pressure

When designing a water main, it is important to consider the type of pipe used and the pressure needs of the water system. Excessive water system pressure can increase the risk of pipe failure and cause customers to wastewater. Distribution system pressure should not exceed 100 psi, unless the design engineer can justify the need for the excessive pressure (to reduce pumping costs, increase fire flow reliability, and for other reasons), and verify that the pipe material is appropriate for this use. See Section 8.5.7 for recommendations on individual pressure-reducing valves.

8.1.8 Surge and Transient Control

Many factors influence hydraulic surges and transient conditions (water hammer), including main size, length, profile and construction materials. See Section 8.2.4 for an analysis of transient conditions. Engineers should base pipe pressure tests and thrust restraint on the maximum transient conditions, including an appropriate safety factor.

There are many ways to provide surge control, including:

- Open surge tanks and pressurized surge tanks.
- Surge anticipator valves, vacuum relief valves, and regulated air release valves.
- Optimize the main size and alignment.
- Electric soft-start or -stop and variable speed drives for pumps.
- Electric interlocks to prevent more than one pump from starting at the same time.
- Slow opening and closing valves.
- Increase the polar moment of inertia of the rotating pump or motor assembly.

It may be necessary to combine methods. Engineers should take care to prevent a protection device from causing a secondary water hammer equal to or worse than the original design.

Reliability of the surge protection facility is important. If appropriate, the design should provide redundancy for essential equipment such as vacuum relief valves. Surge tanks and similar components should have early warning alarms to notify operators. The design should not allow the pumping system to operate if the surge protection facilities are not operable.

8.2 Hydraulic Analysis

Engineers **must** use a hydraulic analysis to size and evaluate a new or expanding distribution system (WAC 246-290-230(1)). Hydraulic analyses take four steps (Cesario 1995; AWWA 2004):

1. **Collect data.** Hydraulic analysis data include physical data on pipes, pumps, reservoirs and valves, and operational data on flows and facility operations.

2. **Develop the model.** Use the data collected to develop a hydraulic model. For simple loop systems or dead-end mains, hand calculations may be adequate. Typically, all but the simplest distribution systems require a computer model for an accurate assessment.
3. **Calibrate the model.** Calibration involves comparing model results with field observations. It is an essential step in developing a useful model (Walski 2000).
4. **Analyze the distribution system.** An adequately calibrated model can analyze the distribution system to determine if it can maintain adequate pressure and develop recommended improvements.

DOH **requires** a detailed hydraulic analysis as part of a purveyor's water system plan (WAC 246-290-100). DOH may also ask a purveyor for an analysis on an "as needed" basis (to resolve an operating problem for example) (WAC 246-290-110(2) and (4)(f)). In all cases, minimum pressures **must** be maintained (chapter 246-290 WAC, Part 3).

8.2.1 Model Development

For small water systems, the computer model usually includes all pipes in the distribution system.

For large water systems, a computer model usually does not include all pipes in the distribution system. It may be appropriate to simplify the water system for the hydraulic analysis. Sometimes, this simplification is called "skeletonization." To reduce the size of the water system model:

- Consider only pipes above a certain size.
- Eliminate "tree type" pipe regions in the water system.
- Replace series and parallel pipes with single equivalent pipes.
- Analyze distinct separate pressure zones separately.

Do not over simplify the model. Minimum requirements for distribution system water-quality models are available from EPA (USEPA 2006). These model requirements include:

- At least 50 percent of total pipe length in the distribution system.
- At least 75 percent of the pipe volume in the distribution system.
- All 12-inch diameter and larger pipes.
- All 6- and 8-inch diameter pipes that connect pressure zones or remote areas of the water system are significant water conveyors, or are otherwise significant.
- All pump stations, storage facilities and control valves.

In all cases, the demands to the regions not modeled can be shown at nodes (junctions) leading to the region eliminated.

8.2.2 Model Calibration

Calibration is an essential part of developing a useful hydraulic model. Engineers often use hydraulic analyses on existing water systems when values for pipe roughness are uncertain or the location and operation of valves or pipes are not clear. The calibration process involves comparing modeled or predicted results with field measurements. This process is necessary for the computer model to provide accurate and reliable results.

Engineers may use various criteria to evaluate model accuracy. The most common are:

- **Absolute pressure difference**. Measured in psi.
- **Relative pressure difference**. Measured as the ratio of the absolute-pressure difference to the average-pressure difference across the water system.

Relative pressure difference is the preferred criterion. Simulations over extended periods involve comparing predicted to observed flow rates, pressures, and tank water levels.

Several things may cause deviations between the model application results and field observations, such as:

- Erroneous model parameters (pipe roughness values and node demand distribution).
- Erroneous network data (pipe diameters and lengths).
- Incorrect network geometry (pipes connected to the wrong nodes).
- Errors in boundary conditions (incorrect pressure-regulating valve settings, tank water levels, and pump curves).
- Errors in historical operating records (pumps starting and stopping at incorrect times).
- Equipment measurement errors (improperly calibrated pressure gauges).
- Measurement error (reading the wrong values from measurement instruments).
- Field data collection error (moving too quickly from one field point to another without allowing the water system to stabilize between readings).

It often takes a repetitive process to eliminate errors, especially when modeling larger water systems. It is most difficult to calibrate very old and corroded distribution systems, and water systems with little or no information, particularly regarding customer water use.

Criteria for Model Calibration

There are no standard national or industry-adopted criteria for calibrating a hydraulic network model. In general, hydraulic modeling used to design facilities or model water quality requires more accurate calibration than models developed for master planning purposes. Engineers can use the references and guidelines in Table 8-1 to calibrate hydraulic models. See the end of this chapter for recommended references on calibrating network distribution models (Bhave 1988; Cesario, 1995; Ormsbee and Lingireddy 1997, Walski 2000).

When calibrating extended-period simulation (EPS) models, the engineer should start with a steady-state hydraulic analysis for pipe roughness, elevations and demand distribution (Walski et al. 2003). As part of developing an EPS model, engineers will need to develop a diurnal demand curve for the water system or pressure zone they are analyzing. See Section 8.2.3 for information on EPS modeling.

Table 8-1: Criteria for Calibrating Hydraulic Models for Planning and Pipeline Sizing

Number of Pressure Readings	Accuracy of Pressure Readings	Number of Flow Readings	Accuracy of Flow Readings	References
2 to 5 percent of nodes	± 2 psi for 90% of readings	3% of pipes	± 5%	ECAC 1999
N/A	± 5% of maximum headloss for 85% of readings ± 7.5% of maximum headloss for 90% of readings	N/A	± 5%, where flow >10 % of the total demand	WRc 1989
N/A	Predict the hydraulic grade line to within 5-10 ft at model calibration points during peak demands, such as fire flows	N/A	N/A	Walski et al. 2003

Model Testing Considerations

For a successful model calibration, engineers must collect necessary data. Data requirements include some:

- Fixed and unchanging parameters (pipe diameter and length).
- Parameters that vary with time (pump rates, reservoir levels, discharge pressures, and demand patterns).
- Parameters that require assumptions (consumption rates and pipe roughness values).

Here are some data-element considerations engineers use to calibrate hydraulic models:

- The modeler should use nominal pipe diameters and adjust pipe roughness values to achieve calibration. If known, actual pipe diameters can be used. Pipe diameter can vary significantly in older pipe, even within the same pipe, and may be irregular and random due to build-up (tuberculation) or corrosion.
- The modeler should use node elevations from topographic maps rather than as-built drawings. These elevations are also closer to the pressure gauge elevations for locations where water systems take pressure measurements.

- Pump curves used in hydraulic simulations should represent the in-situ pump characteristics of the unit. Over time pump impellers wear and can change the pump characteristics. Engineers should determine if the pump curves used are still representative or if they should be updated.
- Water systems that use a supervisory control and data acquisition (SCADA) system must confirm the calibration on devices used to measure tank levels, pressures, and flows for selected locations.
- Without a SCADA system, purveyors should manually track reservoir levels during flow and pressure tests, paying particular attention to the time they take each level reading.
- Engineers should determine operational rules for all major water system components. For example, get answers to these questions:
    - Under what conditions do operators turn on a pump, open or close a control valve, or adjust a pressure-regulating valve?
    - Do reservoir level switches or pressure switches control the pumps?
    - What are the corresponding on-off levels or pressures? Do pumping schedules change to minimize power costs?
    - Are all facilities available, or are some off-line for maintenance or repair?

  These answers are especially critical when running extended-period simulations.
- If possible, the engineer should use good pumping and metered-use records to determine water system-wide demand. However, the distribution of demand over the water system is less well known and, therefore, it may be necessary to redistribute nodal demand.

  For small water systems, it may be possible to gather source and individual meter readings before and after flow tests, and estimate the volume used during the tests. A reasonable way to check the model is to impose actual water system demand and flow test data in a simulation, and then compare predicted residual pressures to those actually measured.
- Because there may be uncertainty about pipe-roughness values in older distribution systems, DOH recommends that engineers adjust operational, consumption, and network data before they adjust pipe-roughness values.

  Pipe-roughness values significantly affect water system flows and pressures during peak hour demands and fire flows. Procedures for hydrant flow tests are in *Installation, Testing and Maintenance of Fire Hydrants* (AWWA 2006). Criteria to identify deficiencies in pipe segments are in *Computer Modeling of Water Distribution Systems* (AWWA 2004). They include:
    - Velocities greater than 5 fps
    - Head losses greater than 10 feet per 1,000 feet
    - Large-diameter pipes (16 inches or more) with head losses greater than 3 feet per 1,000 feet

The accuracy of the calibrated model declines and should be recalibrated whenever significant changes occur in the water distribution network. The engineer should recalibrate the model whenever major new facilities are added to the network system, the peak hour demand or maximum daily demand exceeds that used in the model, or operational procedures change significantly.

8.2.3 Model Analysis

Engineers can use the calibrated model to analyze the distribution system and proposed improvements. The hydraulic analysis should clearly identify how the model was developed and calibrated, and summarize the output. The following items should be in the hydraulic model discussion. These items are also in the hydraulic analysis checklist in Appendix A.

1. Develop a diagram showing all nodes (junctions) used and a corresponding written summary of assumed supply and demand flows for each condition that must be evaluated. Larger scale diagram sheets may be necessary to accurately show proper location and functions of all control valves and pump station facilities.
2. Explain all assumptions used for the model, including friction factors for the pipes and operating conditions of sources, storage reservoirs, booster pumps, and valves. For additions to existing water systems, also provide evidence that the computer model results were compared to actual field measurements, and that the model was calibrated accordingly.
3. Using a system contour map, identify the minimum pressure results found at the highest elevations and other critical areas in each pressure zone of the system under flow conditions found in item 5 (below).
4. Enter pump curves for the proposed source and booster pumps into the program to indicate how the system will respond to varying flow conditions.
5. Steady-state flow conditions to evaluate **must** include each of the following (see WAC 246-290-230(5) and (6)):
    a. PHD in each pressure zone and throughout the water system, under conditions that deplete all equalizing storage volume and assume all sources are operating. The resulting pressures **must** meet the requirements listed in Section 8.1.5.
    b. Highest demand fire suppression flows, such as commercial zones or industrial complexes (>1,000 gpm fire flows, for example), during MDD. The engineer **must** evaluate the water system and each pressure zone under conditions that deplete designed fire suppression volume and equalizing storage. Again, the resulting pressures must conform to Section 8.1.5 with respect to values and locations. The system or zone may also need to be evaluated using the assumption that the most important and largest capacity pump is out of service. See the Water System Coordination Act, WAC 246-293-640 and 660.

    Note: *Items 1 through 5 evaluate the water system's ability to deliver peak flows at minimum pressures. The designer needs to consider the appropriate "worst case scenario" when analyzing the capabilities of the distribution system to deliver water.*

When fire flow is provided, the distribution system **must** provide the required fire flow plus MDD while maintaining distribution system pressures of at least 20 psi when all fire flow and equalizing storage has been depleted (WAC 246-290-230(6)). That said, according to fire protection authorities, while fighting fires, flow rates from fire hydrants depend not on water system design constraints, but on the type of equipment and the number of people involved in fighting the fire. Firefighters will pump as much water from a hydrant as possible to control a fire. Flow rates as high as 2,400 to 3,000 gpm from a single fire hydrant have occurred.

Firefighters have occasionally drawn pressures in the delivery system down below 20 psi. As water system pressure decreases, the pump in the pumper truck eventually begins to cavitate and is unable to deliver any substantial flow rate. At that point, the pump turns off. These conditions could occur even on a water system evaluated and designed at 1,500 gpm per hydrant with 20-psi residual pressure.

Design engineers should evaluate the potential that firefighting equipment may cause very low water system pressure. These low pressures may present a public health concern due to an increased risk for contamination from cross-connections and pathogen intrusion. Options may include discussing water system constraints with fire protection authorities, color-coding fire hydrants to indicate limitations, placing orifice plates or other devices that restrict flow rates, following stringent disinfection O&M procedures after similar events, and informing users of precautions they can use to provide additional protection after experiencing fire flows on the water system.

6. Provide a narrative along with the hydraulic model printouts and data. The narrative should discuss low and high-pressure areas in each pressure zone, identify whether the system has adequate equalizing and fire suppression storage, and propose corrective measures. If submitted as part of a water system plan, the narrative and corrective measures should be in the body of the plan.

Extended Period Simulation

Larger, more complex water systems should consider doing extended period simulation (EPS) (typically a multiple of 24 hours), using model conditions such as ADD, MDD, and a worst-case fire flow event with appropriate hourly peaking factors during the day. These simulations also may be warranted for water systems with limited source capacity and greater reliance on storage facilities to meet demand. Water systems need EPS to understand the effects of changing water usage over time, cycles of draining and filling storage tanks, or the way pumps or valves respond to changes in demand.

As part of developing an EPS model, it is necessary to develop a diurnal demand curve for the water system or pressure zone being analyzed (Cesario 1995). The shape of the diurnal demand curve will vary between water systems. It isn't appropriate to take a diurnal demand curve from a textbook and apply it to an EPS model. Several publications explain how to develop a diurnal demand curve (AWWA 2004; Walski 2003).

8.2.4 Modeling Transient Conditions (Water Hammer)

If the conceptual design or simple manual calculations do not make the engineer confident that the water system is safe from excessive water hammer conditions, the water system should be computer modeled. Furthermore, transmission mains designed to operate at velocities greater than 10 feet per second (10 fps) **must** have a hydraulic transient analysis in conjunction with the hydraulic analysis described above (WAC 246-290-230(9)).

There are various computer programs available to the designer. Many programs designed to perform hydraulic analysis also do transient analyses. It is important to select a model that matches the complexity of the facility. During facility start-up, the engineer should verify modeled results by gradually generating more and more severe conditions. This approach can show the water system works, as predicted, prior to generating the worst-case design conditions.

8.3 Materials

Various materials are available for distribution and transmission pipes. Engineers base their material selection on factors such as life-cycle cost (capital and maintenance), reliability, special design considerations, utility preference or familiarity, conformance with existing materials, and certification under ANSI/NSF Standard 61. The design engineer **must** use established standards, such as AWWA or the American Society for Testing and Materials (ASTM), when justifying the class of pipe selected (WAC 246-290-200(1)).

8.3.1 Third Party Certification

Any selected material that will have substantial contact with drinking water supplies **must** be certified to meet ANSI/NSF Standard 61 (WAC 246-290-220(1)). This applies to coatings, liners, or any joining materials used. "Substantial contact" means the potential for contaminants to enter the drinking water. Factors to consider are the total area of exposure, volume, length of time water is in contact with material, and level of public health risk.

8.3.2 Corrosion Protection

Engineers should consider protection from external corrosion in areas where corrosive soils are prevalent or when pipelines, for whatever reason, leave the soil environment. This protection is especially true for bridge crossings in salt-water (coastal) environments or other harsh environments. This protection may also be necessary in colder locations where salt is used to de-ice roads. Engineers should also evaluate and, if appropriate, protect metal pipes from corrosion due to stray electrical currents in the soil. This usually occurs when metal pipes are near or cross major oil or natural gas pipelines protected by impressed current.

8.3.3 Pipe Water Systems for Seismically Vulnerable Areas

To meet additional state and local requirements, engineers **must** address seismic risk when designing piping water systems (WAC 246-290-200). See Section 13.5 for guidance and requirements on seismic design of piping water systems.

8.4 General Design Considerations for Mains

Engineers should consider the following as part of the general distribution and transmission main design.

8.4.1 Installation

Pipelines should be laid in a public corridor and installed according to established standards such as those from the Washington State Department of Transportation (WSDOT)/APWA or AWWA.

8.4.2 Depth of Pipe Burial

Pipes should be buried below the frost line even in the most severe winters; otherwise, they should be protected against freezing. When determining proper depth, engineers should evaluate temperature variations in the area, especially in Eastern Washington and mountainous areas. The minimum fill depth over the top of the pipe is usually 36 inches. The design engineer may justify another depth (for example, to avoid underground obstructions or rocky conditions). If providing less than 36 inches of cover, pipe load rating should be considered depending on the location of the installation.

8.4.3 Special Design Considerations

The design should protect pipes above ground from freezing (such as bridge crossings) and secure pipes at river crossings or subject to tidal action. The engineer should consider:

- **Pipe thrust restraints** whenever pipelines leave the soil.
- **Underground thrust blocking** whenever a pipe changes direction (such as a bend) or unbalanced thrust forces exist (pressure and momentum).

8.4.4 Separation from Nonpotable Conveyance Systems

The following recommendations apply to pipelines of 24-inch diameter or less. Larger pipelines create more concerns and, therefore, require additional consideration.

DOH recommends that water system designs maintain a 10-foot horizontal and 18-inch vertical separation above nonpotable pipelines (sanitary sewers, reclaimed water piping, irrigation lines, and other uses). The 18-inch vertical separation should be the measured distance between the closest sides of the two pipes. If the nonpotable line is a sewer line, the designer should refer to section C1-9 of *Criteria for Sewage Works Design* (WSDOE 2008) for appropriate sewer design requirements. For additional guidance on potable and nonpotable pipe separation, consult *Pipeline Separation Design and Installation Reference Guide* (WSDOE and DOH 2006).

If site conditions do not allow such minimum separations, pipelines may be closer to each other if the designer identifies and institutes additional precautions to protect the potable line. The lines should be laid in separate trenches. The nonpotable line should be made of materials and joints that meet or exceed water-main construction standards and it should be pressure tested to ensure it is watertight prior to backfilling. There should be at least 5-feet of horizontal and 12-inches of vertical separation between potable water mains and nonpotable conveyance systems.

Potable and nonpotable pipelines may be in a common trench if the horizontal spacing between outer pipe walls is at least 5-feet and the vertical spacing is at least 18-inches from the invert wall of the potable line to the crown wall of the nonpotable line. Both the potable and nonpotable lines should be on a "bench" of undisturbed soil with the nonpotable line below the potable line. If site conditions do not allow these minimum separation distances, both pipelines should be built with casing pipes of pressure-rated pipe material designed to withstand a minimum static pressure of 150 psi. Additional mitigation efforts include impermeable barriers such as encasement with Portland cement or concrete.

For pipe crossings—if the potable line is closer than 18 vertical inches from the nonpotable line or the potable line must cross under the nonpotable line—the potable line should be cased with pressure-rated pipe extending at least 10 feet to either side of the crossing. If the nonpotable line is a sewer line, get appropriate sewer design requirements from Section C1-9.1.4 of *Criteria for Sewage Works Design* (WSDOE 2008).

The design engineer should check with DOH about projects that involve reclaimed water lines to ensure consistency with policies or specifications that specifically apply to such projects.

8.4.5 Separation from Other Potential Sources of Contamination

Design engineers should thoroughly evaluate water main installations on a case-by-case basis if they are near other potential sources of contamination. This may include a facility if a failure at the facility would subject the water in the main to toxic or pathogenic contamination. Other potential sources of contamination include storage ponds, land disposal sites for wastewater or industrial process water containing toxic materials or pathogenic organisms, and solid waste disposal sites.

Purveyors should take precautions before selecting materials for a pipeline in an area with contaminated soils. Research indicates certain pipe materials (polyvinyl chloride, polyethylene, polybutylene, and asbestos cement) and elastomers (such as those used in jointing gaskets and packing glands) may be susceptible to permeation by lower-molecular-weight organic solvents or petroleum products. Purveyors should ask DOH and the manufacturer about permeation of pipe walls and jointing material for use in that area.

8.5 Appurtenant Design Considerations

Engineers should consider the following as part of the overall distribution and transmission main appurtenant design.

8.5.1 Valving

Valving should be sufficient to minimize the number of customers out of service when the water system turns the water off for maintenance, repair, replacement, or additions. On distribution mains with a diameter of 12 inches or less, it should be possible to isolate a length of water main no more than 1,000 feet by closing valves.

8.5.2 Vacuum Relief and Air Release Valves

High points of distribution or transmission lines should have combination vacuum relief and air release valves. Instead of vacuum relief and air release valves, service connections and hydrants may adequately handle vacuum relief and air release functions in the pipeline. This is at the discretion of the designer and utility.

The designer should make an air inlet and discharge vent at least 18 inches above finished grade. It should have a screened downward-facing vent opening. If it is not practical to install an air vent above ground (particularly in areas of winter freezing conditions), it may be below grade if the below-grade chamber is rated for appropriate traffic loading in traffic areas, and the chamber drains to daylight.

8.5.3 Flushing Valves, Blow-offs and Hydrants

To allow sufficient flushing and proper disinfection of distribution mains, engineers should install blow-offs or hydrants at low points and dead-ends in the distribution system. They should be designed to achieve a minimum velocity of 2.5 fps in the main for scouring purposes. To meet these criteria, small water systems with larger pipes may need to consider design allowances that enable them to add temporary pumping or storage facilities.

8.5.4 Fire Hydrants

The Water System Coordination Act defines standard fire hydrants (WAC 246-293-650(3)):

> "All fire hydrants shall conform to American Water Works Association specifications for dry barrel fire hydrants. Each hydrant shall have at least two hose connections of 2½ inches diameter each and one pumper connection."

Although a utility may want to use nonstandard hydrants to provide fire flow, the state rule requires water systems designed to provide fire flows to have a minimum distribution main size of 6 inches (150 mm) (WAC 246-290-230(3)).

Designers should provide all fire hydrants with their own auxiliary gate valve. Auxiliary gate valves are a safety item on hydrants, and most, if not all, utilities require them. New standard fire hydrants are not allowed on pipelines less than 6 inches in diameter (WAC 246-290-230(4)). Other types of "hydrants" not designed to provide fire flows, such as flush valves, standpipes, blow-offs, or nonstandard, smaller volume hydrants without pumper ports may be placed on smaller mains (less than 6 inches in diameter).

8.5.5 Sampling Stations

To avoid false positives in bacteriological samples, DOH recommends the following sampling station design features:

1. Use distribution piping, not household plumbing.
2. The water system should have control (ownership) of the station.
3. It should be an active connection.
4. A dedicated standpipe with a smooth-nosed sample tap is preferable.

To protect the sample against potential contamination, engineers should not use stop-to-waste designs without first considering operations and maintenance, drainage, and security. Purveyors should provide adequate protection from freezing at all stations.

8.5.6 Angle, Curb or Meter Stops

Separate angle, curb, or meter stops should be installed for each service connection. They allow water systems to close individual customer connections temporarily without interrupting service to other customers.

8.5.7 Individual Pressure-Reducing Valves

When a purveyor anticipates pressure in the mains will exceed 80 psi, the purveyor is responsible for recommending that customers install and maintain an individual pressure-reducing valve (PRV) as described in the *Uniform Plumbing Code*. Purveyors should not install a PRV for an individual customer unless they have a written agreement with the customer showing who is responsible for required PRV maintenance, repair, or replacement. The purveyor should check for local ordinances or service agreements on PRV use.

8.6 Layout of Mains

Water mains should be built in segmented grids and loops located in the established right-of-way or utility easement. Distribution mains should be looped, if possible, to avoid as many dead ends as possible. Purveyors should install dead-end mains only under two conditions:

1. Looping is impractical due to topography, geology, pressure-zone boundaries, unavailable easements, or locations of users.
2. The water system plans a main extension in the near future that will eliminate the dead-end condition.

If purveyors cannot avoid dead ends, they should provide blow-offs to allow adequate flushing and cleaning of those mains. Also, see Section 8.5.3.

8.7 Detail Drawings

Construction documents should include complete detail drawings or, if appropriate, a reference to standard system drawings for:

1. A plan view with a scale of no more than 100-feet to the inch.
2. Profiles or crossing details with a vertical scale of no more than 10-feet to the inch for:
   - Areas where pipeline projects encounter utilities that cannot be easily located or that could conflict with the proposed pipeline, such as storm and sanitary sewers.
   - Pipelines proposed through a streambed.

   Note: *Special project conditions may also justify a profile. DOH recognizes that profiles may not be economically justifiable until existing utilities can be field located at construction time. Therefore, it is up to the design engineer to decide when profiles should be prepared.*
3. Location, size, and construction materials of all proposed pipelines in the project area. Show all hydrants, valves, meters, blow-off valves, and other distribution system features.
4. Identification of lots served under the project scope of work by new distribution mains serving plats or subdivisions.
5. Typical construction details of all new pipeline tie-ins to existing pipelines.
6. Typical details of pipeline trench cross-section indicating bedding, backfill, and compaction requirements.
7. Typical details of thrust blocking or restraints.
8. Service connection details, where appropriate.
9. All other buried utilities, including storm and sanitary sewers, dry wells, telephone, natural gas, power and TV cable lines in the project area (existing or proposed concurrent with pipeline construction) to the extent possible, given existing available records. Construction details should note that all buried utilities are to be field located prior to construction.

8.8 Standard Construction Specifications

Construction specifications **must** meet commonly accepted technical standards such as AWWA, WSDOT/APWA specifications or equivalent (WAC 246-290-200(1)(d)). Attention to detail is important to ensure the identified specifications include all required information. The referenced specifications may require some case-by-case determinations. For example, WSDOT/APWA specifications include disinfection procedures for pipelines while another standard, such as AWWA, addresses reservoir disinfection. Therefore, construction specifications often include several alternative disinfection procedures. The final selection is up to the designer or purveyor.

Water systems may include standard construction specifications in the body of their WSP or make them available as a separate document.

The prelude to the specifications should include general water system criteria. That includes specific design criteria, pipe-sizing requirements, securing right-of-ways for projects, and various policies that might apply such as requiring pipe looping in water system extensions.

The standard specifications should:

Describe how the water system ensures developers use the specifications for new development. This may include inspection procedures, certification of extension plans, and filing copies of "as-built" drawings.

Include materials and construction details utilities consider standard for water system construction and maintenance, such as:

- Piping, fittings, fire hydrants, blow-off hydrants, and hydrant guard posts.
- Pressure and vacuum-release valves, pressure-reducing valves, valve boxes, thrust-blocking, pipe bolts, flange gaskets, pipe bedding materials, structural materials in contact with water.
- Water meters, meter boxes, meter setters, corporation stops, service clamps, curb stops.
- Residential, commercial, and industrial service lines.
- Other materials the design engineer determines appropriate.

Include the following construction methods and details:

- ANSI/NSF certification for all materials in contact with the drinking water.
- Trenching alignment (including staking and deviations).
- Trench excavation (depth, width, debris handling, and daily covering requirements).
- Adhere to manufacturer's recommendation for installation and maintenance.
- Tunneling requirements.
- Bridge and highway crossing specifications, and road development or resurfacing,.
- Hydrant installation (including spacing and appurtenances).
- Installation details for underground appurtenances (valves, meters, pressure reducers, and other appurtenances).
- Hydrostatic testing (test conditions, inspections, and allowable leakage).
- Installation and testing of valves.
- Disinfection and flushing of mains and laterals, service connection elements (customer notices, metering, and cross-connection control aspects).
- Any other water system-specific elements the water system and its engineering or planning consultants consider appropriate.

8.9 Cross-Connection Protection

Refer to Section 13.4 for guidance and requirements related to cross-connection protection.

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Chapter 9: Reservoir Design and Storage Volume

Engineers are responsible for designing stable and durable reservoirs that protect the quality of stored water. DOH knows there may be more than one acceptable design concept for a particular reservoir project. Therefore, DOH intends the reservoir design criteria in this chapter to ensure water system adequacy, reliability, and compatibility with existing and future facilities, not to establish any particular design approach. See the references at the end of the chapter for more information on reservoir design (AWWA 1998; Ten State Standards 2007; Kirmeyer et al. 1999; Martel et al. 2002; Walski 2000).

9.0 Storage Volume Components

The engineer for a reservoir design **must** consider each of the five storage components discussed in Section 6.7.3 and listed below (WAC 246-290-235(3)):

1. Operational storage (OS)
2. Equalizing storage (ES)
3. Standby storage (SB)
4. Fire suppression storage (FSS)
5. Dead storage (DS), if any

Figure 9-1 illustrates, and Table 9-1 describes, a typical cross-section of the reservoir storage components. Section 9.0.5 explains when systems can exclude the smaller of the SB or FSS component from their total storage requirement. Section 9.1.3 explains when systems can use alternate designs to reduce or sometimes eliminate ES, SB, and FSS. Only **effective storage**, as defined in Section 9.0.1, can be used to determine the actual available, or design, storage volume.

9.0.1 Effective Storage

Total tank volume, as measured between the overflow and the tank outlet elevations, may not necessarily equal the effective volume available to the water system. **Effective storage volume** is equal to the total volume less any *DS* built in to the reservoir. For example, part of a standpipe's capacity is designed as dead storage. That means that below a certain water surface elevation within the tank, the pressure delivered to some customers falls below minimum pressure requirements for the water system.

Conversely, if a water system's source (well or booster pump) cannot deliver a design flow rate above a certain water surface elevation within the tank, this upper volume of the tank is considered unavailable to the water system and is not a part of the effective storage.

The amount of effective storage may also depend on the location of the storage relative to the place of its use. Is it in a different pressure zone? How far does the water need to travel?

9.0.2 Operational Storage

OS is the volume of the reservoir devoted to supplying the water system while, under normal operating conditions, the sources of supply are in “off” status (WAC 246-290-010). This volume will vary according to two main factors:

1. The sensitivity of the water level sensors controlling the source pumps.
2. The configuration of the tank designed to provide the volume required to prevent excessive cycling (starting and stopping) of the pump motor(s).

OS is in addition to the other storage components. When the reservoir is full, OS provides a safety factor beyond that provided by the ES, SB, and FSS.

There are various water level sensors, including float switches, ultrasonic sensors, and pressure switches. Some can detect water level changes as small as a fraction of an inch. Others require more than a foot. Tank designers must account for the type of level sensor they used to determine the vertical dimension needed for proper operation of the device. Manufacturer’s specifications generally govern the determination of this dimension.

After selecting the pump control device, the tank designer can use the vertical dimension to determine other aspects of tank configuration, such as the width, height, and shape. The OS volume should be sufficient to avoid pump cycling in excess of the pump motor manufacturer's recommendation. In general, limit the motor to no more than six starts per hour. However, many manufacturers warrant more frequent cycling for their pump motors, depending on the size of the pump.

The OS volume in this situation is comparable to the withdrawal volume required when using hydropneumatic tanks for pump motor protection. The *Recommended Standards for Water Works* recommends that the gross volume of the hydropneumatic tank, in gallons, be at least 10 times the capacity of the largest pump, rated in gpm (Ten State Standards 2007). The withdrawal volume of a hydropneumatic tank is usually about 25 percent of the gross volume. Using this relationship, DOH recommends that the OS volume be about 2.5 times the capacity of the largest pump. Calculating the OS volume will verify that typically, for gravity storage tanks, it is substantially less than the remaining volume of the tank. The volume associated with the elevation difference required for the pump level sensors is usually larger than that required for pump motor protection, so that volume becomes the limiting factor when determining the required OS volume.

OS does not apply to water systems operating under a continuous pumping mode (see Section 9.0.3). This operational mode protects the pump motor. The designer needs to consider only the other components of effective storage (ES, SB, and FSS).

9.0.3 Equalizing Storage

When source pumping capacity cannot meet the periodic daily (or longer) peak demands placed on the water system, the water system **must** provide equalizing storage (ES) as a part of total storage (WAC 246-290-235(2)). ES **must** be available at 30 psi to all service connections. Several factors influence the ES volume, including peak diurnal variations in water system demand, source production capacity, and the mode of operation (continuous pumping for a select period or "call-on-demand" through reservoir level control switches).

The designer should use the mode of source pump operation and hydraulic capabilities to evaluate ES requirements for each water system.

1. **Continuous Pumping**
   ES sizing with continuous source pumping will require developing a maximum day demand (MDD) diurnal curve for the water system being evaluated. Diurnal demand varies due to water system size, season, and type of demand (residential, commercial, industrial, and recreational). After developing the MDD diurnal curve, the design engineer can calculate the required ES by determining the difference between supply and demand over the course of the day. Extended period simulation hydraulic models can be used for this purpose. As a general guideline, the volume of ES needed using constant pumping is about 10 to 25 percent of the MDD (Walski 2000).
2. **Call-on-Demand**
   Engineers should use Equation 9-1 to estimate minimum ES requirements unless actual water use records indicate a more applicable volume. Water systems with multiple sources may need to provide ES in excess of Equation 9-1 depending on the mode of operation. This may involve storing multiple days of volume to meet maximum water system demands.

Equation 9-1:

$$\mathbf{ES} = \mathbf{(PHD - Q_S)(150\ min.)}, \text{ but in no case less than zero}$$

Where:

ES	=	Equalizing storage component, in gallons
PHD	=	Peak hourly demand, in gpm, as defined in Chapter5 of this manual
$\mathbf{Q_S}$	=	Sum of all installed and active supply source capacities except emergency supply, in gpm. See Section 9.1.1 for source definitions

3. **Multiple Day Demand**
   The ES volume will increase significantly if the source(s) cannot meet the MDD. In such cases, the design engineer can calculate the difference between supply and demand over multiple days to determine the required ES. This approach requires developing water system-specific diurnal demand curves. Extended period simulation hydraulic modeling may be needed to confirm that minimum pressure requirements can consistently be met.

   Engineers **must** also design distribution reservoirs to maintain water circulation and prevent stagnation (WAC 246-290-235(1)(b)). Long residence times in reservoirs can lead to water quality problems. Complete turnover of the reservoir water should occur at least every 3 to 5 days (Kirmeyer et al. 1999). See Section 9.9 for guidance on maintaining water quality in reservoirs.

9.0.4 Standby Storage

Standby storage (SB) provides a measure of reliability in case sources fail or unusual conditions impose higher demands than anticipated. The SB volume recommended for water systems with one source may differ from that for water systems with multiple sources, as described in the following sections.

1. **Water Systems with a Single Source**
   Water systems served by a single source should have SB volume of twice the water system's ADD for the design year available to all service connections at 20 psi. See Chapter 5 for a definition of ADD. Water systems should consider additional SB volume for surface water sources vulnerable to flooding or other extreme weather events.

Equation 9-2:

$$SB_{TSS} = (2\ \text{days})(ADD)(N)$$

Where:

SB_{TSS} = Total standby storage for a single source water system, in gallons

ADD = Average day demand for the design year, in gpd/ERU

N = Number of ERUs

2. **Water Systems with Multiple Sources**
   Water systems served by multiple sources **should** have SB volume based on Equation 9-3.

Equation 9-3:

$$SB_{TMS} = (2 \text{ days})[(ADD)(N) - t_m (Q_S - Q_L)]$$

Where:

- **SB_{TMS}** = Total standby storage component for a multiple source water system; in gallons
- **ADD** = Average day demand for the design year, in gpd/ERU
- **N** = Number of ERUs
- **Q_S** = Sum of all installed and continuously available supply source capacities, except emergency sources, in gpm. See Section 9.1.1 for the definition of a continuously available source
- **Q_L** = The largest capacity source available to the water system, in gpm
- **t_m** = Time the remaining sources are pumped on the day when the largest source is not available, in minutes. Unless restricted otherwise, assume 1,440 minutes

Note: *Although SB volumes are intended to satisfy the requirements imposed by water system customers for unusual situations (WAC 246-290-420), DOH recommends that SB volume be no less than 200 gallons/ERU.*

3. **Standby Storage for Recreational and Non-critical Commercial Uses**
   Recreational water systems serve recreational lots that, through covenant or other means, have no permanently fixed-in-place residential structures. DOH has no SB recommendation for recreational water systems or water systems made up entirely of the noncommunity uses below:

   - RV parks
   - Campgrounds
   - Fair grounds
   - Outdoor concert grounds
   - Restaurants
   - Non-critical commercial uses

   If a loss of water-supply event occurs, these water systems could shut down without affecting public health and welfare.

4. **Standby Storage for Noncommunity Uses**
   DOH recommends that nontransient noncommunity water systems such as schools, hospitals, and recreational-residential water systems serving permanent fixed-in-place residential structures provide SB.

   - If these water systems rely on a single source, their SB is defined in Section 9.0.4(1).
   - If they have multiple sources, their SB is defined in Section 9.0.4(2).
   - Engineers **must** determine noncommunity water demands as defined in WAC 246-290-221(2). See Chapter 5 for recommended criteria that apply to noncommunity water uses.

5. **Reduction in Standby Storage**
   The purveyor and water system designer have various options available to decrease the volume of SB in the water system. As Section 9.0.4(2) indicates, they may reduce the volume if they develop additional supply sources. For DOH to consider SB equivalent to gravity storage, the sources must have auxiliary power that starts automatically if the primary power feed is disrupted.

   The purveyor may also reduce the volume if community expectations are amenable to a lesser SB capacity. That means they agree that the volume for one average day of service is sufficient for standby purposes instead of two days. A utility may also make better use of dead storage by providing booster pumps at the point where the pressure reaches the minimum established by the community in situations when the SB is used.

9.0.5 Fire Suppression Storage

The local fire protection authority or county fire marshal determines a fire flow requirement for water systems. This fire suppression storage (FSS) level depends on the maximum flow *rate* and *duration*. Water systems **must** build and maintain facilities, including storage reservoirs, capable of meeting fire flow requirements while maintaining 20 psi pressure throughout the distribution system (WAC 246-290-221(5)).

Water systems in areas governed under the Public Water System Coordination Act *of 1977* (chapter 70.116 RCW), **must** meet the minimum flow rates and durations for residential, commercial, and industrial developments specified in the Water System Coordination Act (see Section 10.1) (WAC 246-293-640). The local fire protection authority, county fire marshal, or a locally adopted coordinated water system plan, may specify greater FSS requirements.

Minimum FSS Volume

The minimum FSS volume for water systems served by single or multiple supply sources is the product of the required flow rate (expressed in gpm) multiplied by the flow duration (expressed in minutes). See Equation 9-4.

Equation 9-4:

$$FSS = (FF)(t_m)$$

Where:

FF = Required fire flow rate, expressed in gpm, as specified by fire protection authority or under WAC 246-293-640, whichever is greater

t_m = Duration of FF rate, expressed in minutes, as specified by fire protection authority or under WAC 246-293-640, whichever is greater

Consolidating Standby and Fire Suppression Storage (nesting)

Water systems can exclude the SB or FSS component, whichever is smaller, from a water system's total storage requirement unless such practice is prohibited by: (1) a locally developed and adopted coordinated water system plan, (2) local ordinance, or (3) the local fire protection authority or county fire marshal (see WAC 246-290-235(4)).

9.0.6 Dead Storage

Dead storage (DS) is the volume of stored water not available to all consumers at the minimum design pressure (WAC 246-290-230(5) and (6)). The reservoir- and water system-capacity analysis should clearly identify the DS volume.

9.0.7 Storage Used for Treatment Purposes

Water systems sometimes need storage volume to provide adequate contact time for routine disinfection or to meet surface water treatment requirements. When water systems need storage volume to meet a water treatment requirement, the designer must determine the volume necessary. The designer must describe how the reservoir design and configuration will provide adequate treatment and public health protection under all reasonably anticipated operating conditions. The engineer should not consider FSS or SB volume part of this volume.

The designer should ensure the water system owner understands that the risk to public health will increase if or when the storage volume is decreased and eventually depleted. It is also important to understand that a treatment technique violation can occur whenever storage is insufficient to provide the required disinfectant contact time. The owner or community may want to increase storage volumes to reduce that risk. DOH recommends that storage volume required to meet surface water treatment requirements be separate from the distribution storage provided.

9.1 Reservoir Sizing Considerations

Water systems may reduce all storage volumes if reliable source water is available to meet all demands at the required flow rate and duration. Following are some elements to evaluate when considering reductions for the designed storage volumes.

9.1.1 Source Definition Used in Sizing New Reservoirs

Engineers may consider any source classified as “permanent” or “seasonal” when designing new reservoir facilities if the source is **continuously available** to the water system and meets, at a minimum, all primary drinking water standards (WAC 246-290-010, 222(3), and 420(2) and (5)).

“Continuously available to the system” means all of the following:

- The source is equipped with functional pumping equipment (and treatment equipment, if required).
- The equipment is exercised regularly to ensure its integrity.
- Water is available from the source year round.
- The source activates automatically based on pre-set parameters (reservoir level, water system pressure, or other conditions).

For designing new reservoir facilities, DOH considers the following as sources:

1. Each pump in a booster pump station (pumps installed in parallel, not series) pumping into the zone served by that particular reservoir.
2. Each independent, parallel treatment train in a water treatment facility.
3. Each well, or well field comprised of wells, constructed according to the Minimum Standards for Construction and Maintenance of Wells (chapter 173-160 WAC) and capable of pumping concurrently as justified by actual pump test records.
4. Each pump installed in a large capacity, large diameter well if the water system can take each pump out of service without interrupting the operation of any other pump.
5. An emergency intertie, if all the following conditions are met:
    - It is equipped with an automatic valve.
    - There is an intertie agreement that specifically includes provision of SB, FSS, or both.
    - The intertie, supplying, and receiving distribution systems have sufficient hydraulic capacity to deliver the allocated flow at no less than the minimum pressure required by WAC 246-290-230. If the intertie requires booster-pumping facilities, then each pump installed in parallel constitutes a source.
6. A pressure reducing valve between pressure zones within the same water system if both:
    - Adequate volume is available in the upper zone’s storage facilities.
    - The distribution system (from the upper zone through the PRV to the end use in the lower zone) has the hydraulic capacity to deliver the allocated flows to meet or augment peak hour flows or fire flows, at no less than the minimum pressure required by WAC 246-290-230.

Engineers need to use the actual installed capacity of the facilities and equipment when determining physical capacity based on storage requirements for existing water systems.

9.1.2 Storage for Consecutive Water Systems

A "consecutive water system" purchases all of its water supply from another regulated water system. Consecutive water systems may use the storage available from the supplying water system to satisfy the requirements of Chapter 9, if they meet two conditions:

1. The wholesale water agreement between the supplying water system and the consecutive water system defines the quantity of ES, SB, and FSS the supplying water system specifically reserved for the consecutive water system.
2. The engineer can demonstrate that both the supplying and consecutive water systems can satisfy the hydraulic design criteria described in Sections 8.2.3 and 9.3.

9.1.3 Alternate Design Concept

If the water system design includes multiple supply sources and, in some cases, on-site standby power, the engineer may reduce or, in some cases, eliminate the ES and SB components summarized in Section 9.0. The engineer may eliminate ES only if the combined capacity of the supply sources meets or exceeds the PHD for the water system, or the pressure zone, with 30-psi pressure provided at each existing and proposed service connection. The engineer may reduce or, in some cases, eliminate FSS if the water system design includes on-site standby power and the water system has multiple supply sources capable of providing the fire-flow rate in addition to the MDD rate for the water system. The engineer should verify this with the local fire protection authority.

Water systems substituting source capacity for storage volumes must consider and provide appropriate justification for varying from each of the following criteria:

1. Exclude the capacity of the largest producing supply source from the calculations.
2. Equip each supply source used in the calculations with on-site backup power facilities, promptly started by an automatic transfer switch upon loss of utility power.
3. Incorporate provisions for pump protection during low demand periods into the water system design.

9.1.4 Design Life

Storage facilities are designed to serve the needs of the community for a planned number of years, or to accommodate full water system build-out (for a particular subdivision, planned development, or as a condition of plat approval). The design life for properly maintained concrete and steel storage tanks is about 50 years. Before considering any type of storage tank that does not have the historical longevity of these tanks, the engineer should evaluate it on a life-cycle-cost basis. DOH discourages the use of thin walled and polymeric tanks because they have a shorter design life and are more susceptible to storm damage, ultraviolet degradation, and gunfire.

9.2 Establishing Overflow Elevations

Considerations for establishing overflow elevations for reservoirs designed to provide gravity water service include:

1. **Consistency with other facilities and plans**
   The overflow elevation should be consistent with other storage facilities the water system uses or plans to use. The designer should also consider the overflow elevation of existing or proposed facilities at other nearby water systems.
2. **Consistency with pressure requirements and limits**
   The tank overflow elevation should be consistent with pressure requirements and pressure limitations within the existing and future water-service area. The designer should consult topographic maps in addition to information received from the water system hydraulic analysis described in Section 8.2.
3. **Consistency with source capacity**
   Engineers should coordinate tank elevation and tank geometry with source equipment discharge-head characteristics to ensure they meet DOH-established source capacity requirements. They should also develop pump curves and prepare detailed hydraulic analyses of existing and future distribution-system conditions (pipe network and water demand).
4. **Maintaining levels**
   To maintain levels in reservoirs throughout the water system, engineers should use altitude valves where appropriate.

9.3 Water System Pressure Considerations

This section describes the hydraulic design criteria for new and existing water systems. Figure 9-1 is a graphic view of the reservoir hydraulic design criteria described below. Chapter 5 defines peak demand periods, including MDD and PHD.

9.3.1 Fire Suppression Storage Component

For water systems supplied through gravity storage, the bottom of the FSS component **must** be at an elevation that produces no less than 20 psi at all points throughout the distribution system under the MDD rate plus fire flow conditions (WAC 246-290-230(6)). If pumping supplies some of the fire flows, DOH recommends an analysis be completed using the assumption that the largest source is out of service. This assumption and analysis **is required** under the Water System Coordination Act (WAC 246-293-600).

Any one or combination of design parameters including the tank elevation, tank geometry, tank location, or the distribution piping network may be modified to meet the 20 psi residual pressure standard. The design engineer is responsible for providing evidence of a hydraulic analysis as described in Section 8.2.

9.3.2 Standby Storage Component

The lower elevation of the SB component should produce no less than 20-psi at all existing and proposed service connections throughout the distribution system under PHD conditions, assuming that the largest source is not in service.

The design engineer may modify one or a combination of design parameters to meet the 20-psi residual pressure (including tank elevation, tank geometry, tank location, or the piping network). The engineer must provide evidence of a hydraulic analysis as described in Section 8.2.

9.3.3 Consolidating (Nesting) Standby and Fire Suppression Storage

If the designer plans to consolidate SB and FSS (WAC 246-290-235(4)), the storage-volume elevation evaluation must meet the requirements in Section 9.3.1 above. The evaluation at higher elevations or pressures is necessary only if the local community establishes a higher level of service for conditions under which standby storage is used.

9.4 Site Feasibility Considerations

Site feasibility considerations should include:

1. Sufficient area to build and maintain the facility and construct future storage to meet projected growth.
2. Distance to the existing distribution and transmission system.
3. Need for new distribution and transmission pipelines to meet pressure standards.
4. Existing ground-surface elevation and site drainage.
5. Site access, anticipating potential seasonal limitations.
6. Geotechnical engineering field investigations including:
    a. Foundation design requirements.
    b. Soil type and soil-bearing strength.
    c. Groundwater table elevation.
7. Availability of power.

9.5 Special Design Considerations Based on Type of Reservoir

Special design considerations for ground level and below-grade reservoirs improve water system reliability and prevent contamination of stored water. Engineers should consider backup power supplies, grading surrounding soils, and other design aspects described in the following sections.

Some standard reservoir designs eliminate the need to submit basic structural design information. However, all reservoir submittals **must** include the site-specific design information required by chapter 246-290 WAC, Part 3. Additional guidance on site-specific design requirements appears throughout this chapter.

9.5.1 Backup Power Recommendations for Non-Elevated Reservoirs

DOH recommends that water systems relying on non-elevated reservoirs (reservoirs that can only supply a distribution system in whole or in part through a booster pump station) have onsite backup power facilities or, at least, be able to connect easily to a portable generator. See Chapter 10 for booster-pump design guidelines. DOH recommends backup power facilities that start through an automatic transfer switch if a utility power supply interruption occurs. Manual transfer may be sufficient if it can occur within a reasonable time according to established operating procedures. Our primary intent for recommending backup power is to minimize cross-connection contamination concerns by keeping the water system pressurized at all times.

9.5.2 Ground Level and Underground Reservoirs

The following recommendations apply to ground level, partially buried, and underground reservoirs:

1. Ground level, partially buried and underground reservoirs should be outside the 100-year flood plain.
2. Water systems should grade the area surrounding a ground level or below-grade reservoir to prevent surface water from standing within 50 feet of the structure, at a minimum.
3. When the reservoir bottom is below normal ground surface, it should be above the groundwater table, if possible. If this is not possible, special design considerations should include providing perimeter foundation drains to daylight and exterior tank sealants. These are necessary to keep groundwater from entering the tank and to protect the reservoir from potential flotation forces when the tank is empty.
4. Partially buried or underground reservoirs should be at least 50 feet from sanitary sewers, drains, standing water, and similar sources of possible contamination. If gravity sewers are within 50 feet of the reservoir, engineers should use the same type of pipe used for water mains. These pipelines should be pressure tested in place to 50 psi without leakage.
5. The top of the reservoir should be at least 2 feet above normal ground surface, unless special design considerations address maintenance issues and prevent surface contamination.

9.6 Reservoir Appurtenant Design

All reservoir appurtenances should be designed to be water tight and protected against freezing and ice damage, which will interfere with proper functioning (such as tank level controls, riser pipes, overflows, and atmospheric vents). These appurtenances **must** be designed to prevent entry by birds, animals, insects, excessive dust, and other potential sources of external contamination (WAC 246-290-235(1)).

9.6.1 General

Engineers should consider the following elements as part of the overall reservoir appurtenances design:

1. Reservoir isolation valve(s), which permit isolating the tank from the water system (WAC 246-290-235(1)).
2. Air release/vacuum release valve on the distribution system side of the isolation valve.
3. Smooth-nosed sample tap on the tank side of the isolation valve (WAC 246-290-235(1)).
4. High- and low-level alarm system that directly notifies operations personnel.
5. Local level indication, either a pressure gauge measured in "feet," or an exterior site gauge.
6. Designed and installed drain facilities (see Section 9.6.2).
7. Designed and installed overflow pipe (see Section 9.6.3).
8. Tank atmospheric vents, with a non-corroding insect screen (see Section 9.6.4).
9. Security features to protect stored water from contamination due to unauthorized entry or vandalism (WAC 246-290-235(1) (see Section 9.6.7)).
10. Water tight, insect proof access hatches, vents (WAC 246-290-235(1)).
11. Access ways and ladders necessary to provide access for safe maintenance.
12. Lightning arresters and electrical grounding, as applicable.
13. Silt-stop on the outlet pipe to keep sediment from entering the distribution system.
14. Leakage testing and disinfection per accepted standards, such as AWWA.
15. Slope of reservoir roof at least 2 percent (¼ inch per foot).
16. Piping material below the reservoir and extending at least 10 feet from the perimeter of the structure constructed of sturdier materials (see Section 9.6.6).
17. Separate inlet and outlet pipes to and from the reservoir, or other provisions, that effectively turnover stored water. The separate pipes should be on opposite sides of the reservoir and, preferably, at different elevations to prevent or minimize short-circuiting (see Section 9.9).

9.6.2 Reservoir Drains

Reservoir designs **must** include drain facilities that drain to daylight or an approved alternative that is adequate to prevent cross-connection contamination (WAC 246-290-235(1)). The facility should be able to drain the full contents of the tank without water entering the distribution system or causing erosion at the drainage outlet. DOH does not allow any connection to storm sewers or sanitary sewers without design features to prevent cross contamination, such as a properly designed air gap.

If the topography makes a drain to daylight unfeasible, the reservoir design should include a sump that can be pumped out to empty the reservoir completely.

The reservoir drain should be separate from the outlet pipe to minimize the risk of a cross connection and prevent sediment from entering the distribution system. If an outlet pipe serves as a reservoir drain, it should have a removable silt stop in the reservoir.

Drain lines may discharge directly to a dedicated dry well if the well's design and construction protect against backflow into the reservoir or distribution mains.

9.6.3 Reservoir Overflows

Reservoirs designs **must** include an overflow pipe with atmospheric discharge or other suitable means to prevent cross-connection contamination (WAC 246-290-235(1)). Overflow lines should extend down to an elevation of 12 to 24 inches above ground level and discharge into a splash plate or rocked area. DOH does not allow any connection to storm drains or sanitary sewers without design features to prevent cross contamination, such as a properly designed air gap.

Overflows **must** be covered with a 24-mesh non-corrodible screen or mechanical device, such as a flap valve or duckbill valve, to keep animals, insects or other sources of contamination out of the reservoir (WAC 246-290-235(1)). To confirm the integrity of the screens or mechanical devices, discharge end pipes **must** be located where they can be inspected as part of routine maintenance (WAC 246-290-235(1)(c)).

9.6.4 Reservoir Atmospheric Vents

Reservoirs **must** have a screened roof vent (WAC 246-290-235(1)). DOH does not consider overflows to be vents. To be effective, vents should allow air into the reservoir at a rate greater than or equal to the water withdrawal rate. This will prevent implosion or structural damage to the reservoir. The designer should consider ways to keep the vents from being plugged or restricted, prevent frosting or freezing, and protect against vandalism.

Upward facing vents may not be used in any application. Vents **must** have screens to keep birds or animals out of the reservoir (WAC 246-290-235(1)). For elevated tanks and standpipes, 24-mesh non-corrodible screen may be used. Vents for ground level or underground reservoirs should end in an inverted "U" with the opening 24 to 36 inches above the roof or ground and covered with 24-mesh non-corrodible screen. Screens on ground-level reservoir vents should be inside the pipe at a location minimally susceptible to vandalism.

9.6.5 Roof Drainage

The reservoir roof should be well drained. The reservoir roof should slope at least 2 percent (¼-vertical-inch per horizontal foot). To avoid possible contamination, downspout pipes **must not** enter or pass through the reservoir (WAC 246-290-490).

9.6.6 Piping Material

Engineers should use sturdy material for pipelines constructed directly below the reservoir, such as ductile iron pipe or AWWA C205 steel pipe with a corrosion-resistant coating inside and out. These pipelines should extend to at least 10 feet from the perimeter. This pipeline will be difficult and expensive to repair or replace after the reservoir is in place.

9.6.7 Reservoir Security

Water systems use three types of security measures to protect reservoirs and other water system facilities:

1. **Detect:** Video surveillance, intrusion monitors, and other sensors signal unauthorized access to a facility.
2. **Delay:** Products such as gates, locks, and fencing make it more difficult for an unauthorized person to gain entrance.
3. **Respond:** Security guards and local law enforcement often ***respond*** to unauthorized intrusions.

Comprehensive guidelines on water system security are available from AWWA and other professional organizations. These free guidance documents provide specific design recommendations to improve security at reservoirs and other water system facilities (ASCE 2004; ASCE 2006). The EPA lists security products online at http://cfpub.epa.gov/safewater/watersecurity/guide/tableofcontents.cfm

9.7 Operational Constraints and Considerations

DOH expects all new reservoir designs to meet all applicable Occupational Safety and Health Act (OSHA) and Washington Industrial Safety and Health Act (WISHA) requirements. In addition, engineers should consider the following reservoir design and construction issues:

1. Disposal of chlorinated water after construction and disinfection.
2. Disposal of tank drain-line outflow and tank overflow stream.
3. Effect on water system operation if the new reservoir is taken off-line for maintenance or cleaning.

9.7.1 Valving

The reservoir design **must** include a way to isolate the tank for maintenance (WAC 246-290-235(1)). Engineers can meet this requirement by providing an isolation valve(s). There should be a combination air-release/vacuum-relief valve on the distribution side and a smooth-nosed sample tap on the tank side (for required sample collection).

9.7.2 Reservoir Level Control

All new reservoirs should have a control system to maintain reservoir water levels within a pre-set operating range (OS). Engineers should include the normal high- and low-water surface elevations that define this operating range in the design. The water system should install a high- and low-level alarm system to notify operation personnel directly, and a local level indicator, such as a pressure gauge or exterior site gauge measured in "feet."

Cable-supported float switches are inappropriate if there is a potential for ice formation in the reservoir. Under these conditions, engineers should evaluate alternate ways to control and monitor the tank level.

9.8 Reservoir Structural Design

Engineers **must** consider seismic risk when designing reservoirs (WAC 246-290-200). Refer to Chapter 13, Section 13.5.2 for additional guidance on seismic design of reservoirs.

9.9 Reservoir Water Quality

Long detention times and inadequate mixing can degrade water quality in reservoirs. Stagnant conditions also provide an opportunity for chemical and microbial contamination of the stored water. Therefore, engineers **must** design distribution reservoirs to maintain water circulation, prevent stagnation, and provide adequate disinfection contact time (WAC 236-290-235(1)). Chemical contamination also can occur in newly constructed reservoirs and those with protective coatings.

9.9.1 Water Circulation and Stagnation

Poor water circulation and long detention times in reservoirs can lead to loss of disinfectant residual, microbial growth, sediment accumulation, formation of disinfection byproducts, taste and odor problems, and other water quality issues (AWWA and EES 2002; NRC 2005). A properly designed reservoir can minimize the potential for these problems.

Engineers should evaluate the following design features to improve reservoir water quality:

1. **Orient inlet and outlet to promote mixing.** Poorly mixed reservoirs can lead to stagnant zones where the water age exceeds the average water age in the facility. A properly designed inlet promotes mixing. Water entering the reservoir can create a jet that entrains ambient water effectively mixing the reservoir (Grayman and Kirmeyer 2000). For effective mixing, the inlet flow must be turbulent and have a long enough path for mixing to develop.

   Reservoirs that float on the water system, especially those with single inlet-outlet designs, probably won't have sufficient inflow to mix the reservoir adequately. Special valve arrangements, using one or more check valves on a single inlet-outlet pipe, can be used to promote mixing. Some reservoirs may need specialty mixers to prevent stagnation.

2. **Minimize temperature differences in the reservoir.** Temperature differences as small as 1°C can cause thermal stratification, especially in tall tanks with large diameter inlets located near the bottom. To decrease the potential for thermal stratification, locate the inlet off the bottom of the reservoir and increase the inlet momentum (defined as velocity x flow rate). To increase inlet momentum, decrease the diameter of the inlet pipe. Longer fill cycles also promote mixing by increasing the time for circulation patterns to develop.
3. **Increase the frequency of reservoir turnover.** Although not an absolute standard for stored water, there is a high risk for water quality problems to develop when reservoir turnover time exceeds five days, especially in warmer parts of the year. As a starting point, complete turnover of reservoir water should occur at least every three to five days (Kirmeyer et al. 1999).
4. **Site reservoir to promote turnover**. Reservoirs located at the edge of a pressure zone, or beyond, have longer detention times than those within the pressure zone (Edwards and Maher 2008). Distribution system models that evaluate water age, as well as water system hydraulics, can be useful in evaluating reservoir sites.
5. **Evaluate other engineering considerations**. Temperature gradients in the stored water cause thermal stratification. For this reason, some water systems apply light or reflective protective coatings to the tops of their reservoirs. Tall, narrow standpipes are more prone to thermal stratification than reservoirs with roughly equal height and diameter (Grayman and Kirmeyer 2000).

9.9.2 Tank Materials in Contact with Potable Water

All additives, coatings and compounds that will substantially contact drinking water, such as those listed below, **must** have ANSI/NSF Standard 61 certification (WAC 246-290-220). These materials must be applied carefully, according the manufacturer's recommendations. To avoid unnecessary public health concerns and consumer complaints on aesthetic qualities, the design engineer should address the following concerns:

1. For concrete tanks, use appropriate form-release agents, concrete surface sealants, and admixtures. See Appendix H for guidance on water quality concerns associated with concrete in contact with potable water.
2. For steel tanks, consider the materials used to prepare the surface of the tank, as well as the painting or coating water systems used to protect against corrosion. Cathodic protection should be provided as necessary (especially for underground or partially buried tank installations).
3. Reservoir membrane liners, plastic tanks, fiberglass tanks, or other materials that substantially contact drinking water **must** be ANSI/NSF Standard 61 certified.

4. It is important to follow the manufacturer's instructions when applying protective coatings. Temperature, ventilation, and the thickness of the applied layers affect the time required to cure coatings and the potential for contaminants to leach into the water. If there is any concern over the curing of the coatings and materials, or leaching from the reservoir liner, DOH may require additional water quality monitoring from the reservoir before it goes into service. Appendix H includes additional guidance on testing materials that leach.

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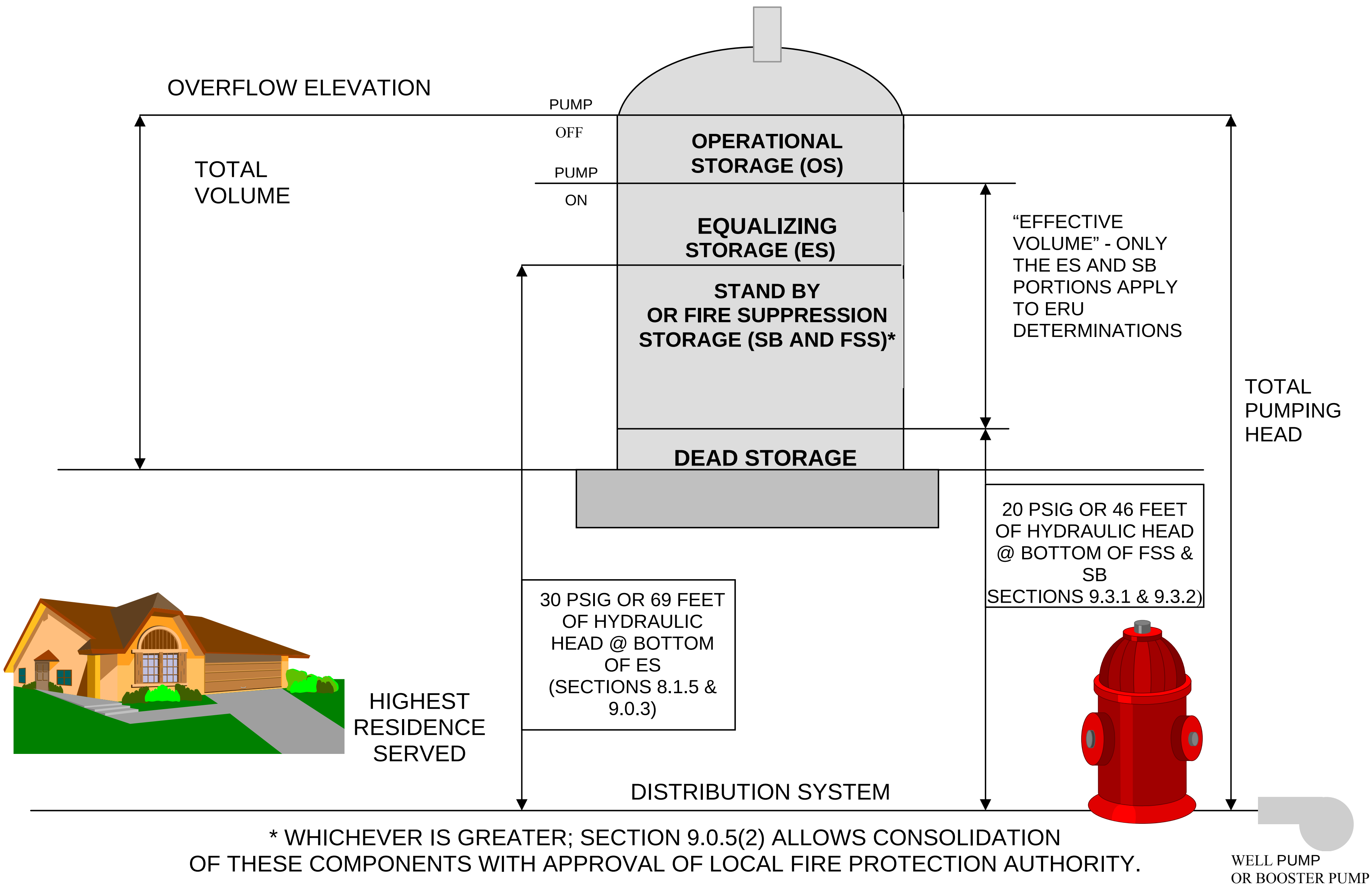
Table 9-1: Reservoir Storage Component Cross-Section Diagram

High Level Alarm. Overflow above ***pump off*** elevation

Pump Off All Pumps On	**Operational Storage (OS) Component** Not part of ES. Not applicable for continuous pumping systems. OS = Operational storage component (gallons).
         Maintain 30 psi (required)	**Equalizing Storage (ES) Component** For call-on-demand: ***ES = (PHD - Q_S)(150 min.),*** but in no case less than zero. *ES* = Equalizing storage component (gallons). *PHD* = Peak hourly demand (gpm). Q_S = Total of all permanent and seasonal sources (gpm). See Section 9.0.3 for sizing criteria for continuous pumping operations.
Low Level Alarm Maintain 20 psi (required)	**Fire Suppression Storage (FSS) Component** For Single Sources and Multiple Sources: ***FSS = (FF)(t_m)*** FSS = Fire suppression storage component (gallons). FF = Needed fire flow rate, expressed in gpm as specified by fire authority or the Coordination Act, whichever is greater. t_m = Duration of FF rate, expressed in minutes as specified by fire authority or the Coordination Act, whichever is greater.
           Maintain 20 psi (recommended)	**Standby Storage (SB) Component** For Single Sources: ***SB_{TSS} = (2 days) (ADD)(N)*** For Multiple Sources: ***SB_{TMS} = (2 days)[(ADD)(N) - t_m(Qs-Q_L)]*** *SB* = Standby storage component per local community expectations (gallons). *TSS, TMS* = Total for water systems with a single source and multiple sources, respectively. *ADD* = Average daily demand for the design year (gpd/ERU). Q_S = The sum of the all source of supply capacities continuously available to the water system (gpm). Q_L = The installed capacity of the largest source (gpm). *N* = Number of ERUs. t_m = Time that remaining sources are pumped when the largest source is not available (minutes). A minimum SB volume sufficient to provide at least 200 gallons per ERU is recommended.
	Dead Storage (DS) Portion of a gravity reservoir that does not provide required minimum pressure.

Figure 9-1: Reservoir Storage Components



Chapter 10: Booster Pump Station Design

Booster pumps work with pressure tanks, variable frequency drives, control valves, and finished water reservoirs to maintain a consistent pressure range in the distribution system. This chapter covers DOH's requirements for booster pump stations. These requirements include meeting minimum design pressures and reliability standards (WAC 246-290-230 and 420).

10.0 Selecting the Booster Pump Station Type

A booster pump station (BPS) may serve an ***open system*** or ***closed system.*** The project design engineer is responsible for selecting the appropriate system for the proposed application. Factors that affect the selection include location, terrain, service area size, required flow rate, costs, difficulty of operation, and reliability of the power supply.

10.0.1 Open System - Definition

An open system BPS transfers water to a higher-pressure zone where the water surface is open to the atmosphere. For example, an open system BPS pumps out of an atmospheric storage tank or distribution system into a separate distribution system and higher atmospheric storage tank. Water surface elevation in the higher storage tank directly or indirectly controls the pump operation.

10.0.2 Closed System - Definition

A closed system BPS transfers water to a higher-pressure zone closed to the atmosphere. For example, a closed system BPS:

1. **Pumps out of an atmospheric storage tank or distribution system into a separate, closed distribution system.** Typically, pre-set discharge pressure settings or flow-rate settings control pump operation and at least one pump runs continuously. Two installed valves prevent system over-pressurization or pump damage, a pump discharge pressure-reducing valve that maintains constant pressure and a valve that returns part of the pump discharge to the storage tank or suction side of the pump.
2. **Pumps out of an atmospheric storage tank or distribution system into a higher-pressure zone, equipped with a pressure tank.** Prescribed pressure settings in the pressure tank control the pump operation (usually on or off). See Chapter 11 for pressure-tank design criteria.

10.0.3 Approach to Booster Pump Station Design Guidelines

There is likely to be more than one acceptable BPS design concept for any particular project. DOH provides these pump station design guidelines not to specify a particular design concept, but as a way to ensure water system adequacy, reliability, and compatibility with existing and future facilities.

For existing water systems, water suppliers may install “individual service” booster pumps to meet minimum pressure requirements. However, water systems may only use individual booster pumps on an “interim basis” and they **must** manage and control any individual booster pumps (WAC 246-290-230(8)).

“Interim basis” means until they make the improvements needed to resolve pressure deficiencies. Water suppliers should describe the time they need to upgrade a water system in a water system plan (WAC 246-290-100(9)), small water system management program, or project report. Because water systems must update their water system plans every six years, DOH expects the interim period to be no longer than six years.

If the pressure in the distribution line meets the minimum requirements, a purveyor may allow installation of more or less permanent individual booster pumps to serve customers who want additional pressure. For example, developers may install booster pumps to serve structures built at significant elevations above the service meters. The purveyor should approve the design, installation, and operation of such individual booster pumps. Moreover, the purveyor **must** ensure the booster pumps do not adversely affect pressure in the rest of the distribution system (WAC 246-290-230 and 420), and address all cross-connection control concerns (WAC 246-290-490).

10.1 Determining Pumping System Discharge Capacity Requirements

Engineers **must** design a BPS to meet peak hourly demand (PHD) (WAC 246-290-230). See Chapter 5 for ways to estimate PHD.

In most cases, the BPS **must** also meet fire flow plus maximum day demand ((WAC 246-290-230(5)). The local fire protection authority or county fire marshal usually determines minimum fire flow requirements (WAC 246-290-221(5)). If these officials don’t adopt local standards, water systems **must** meet the following minimum fire flow standards where required under WAC 246-293-640):

- **Residential:** 500 gpm for 30 minutes
- **Commercial and multifamily:** 750 gpm for 60 minutes
- **Industrial:** 1,000 gpm for 60 minutes

10.1.1 Open System Design Guidelines

For open systems, equalizing storage is available to help meet PHD requirements. Given this available storage, the engineer **must** only design an open system BPS to meet the MDD for the system or a specific pressure zone (WAC 246-290-230). If the BPS constitutes a critical part of the water system, the engineer should consider additional capacity or redundancy for purposes of expansion or reliability. At a minimum, DOH expects the design to ensure the water system can meet the MDD with all pumps in service and the average day demand (ADD) with the largest pump out of service.

For an open system BPS, the engineer should analyze fire-flow capability needs in conjunction with the fire suppression storage provided in the relevant pressure zone. See Chapter 9 for a discussion on fire flow provisions for open system BPSs.

10.1.2 Closed System Design Guidelines

The pumps in a closed system BPS supply the entire flow and pressure required by the service area. Because the rule requires the water system to provide PHD at no less than 30 psi at all service connections throughout the distribution system, DOH expects the engineer to design a closed system to meet this requirement (WAC 246-290-230(5)). For reliability purposes, DOH recommends the BPS provide this capability when the largest capacity booster pump is out of service.

A closed system BPS **must** also be capable of meeting fire suppression requirements, if required, by the fire pump(s), or a combination of fire pump(s) and domestic pump(s). The pumping system **must** be capable of maintaining a minimum of 20 psi at ground level at all points in the distribution system while supplying flow under the condition described in WAC 246-290-230(6).

If the water system is in an area governed by the Water System Coordination Act (chapter 246-293 WAC), fire flow **must** be met when the largest capacity booster pump that is "routinely used" to meet normal daily or peak water system demands is out of service (WAC 246-293-660(1)). For some applications, water systems may install a single separate pump dedicated to fire demands. DOH will not consider this pump "routinely used" if the water system designed and installed it for fire demands only.

10.1.3 Design Life

DOH recommends that engineers design booster pumping facilities to accommodate at least the next 10 years of water system development, and preferably the period associated with full water system build-out for a specific subdivision or planned development or as a condition of plat approval, or any other period justified in a water system plan or project report.

10.2 Hydraulic Design Requirements for Supplying Systems

A BPS designed to draw water from a distribution system to supply a separate high service area directly affects the supplying distribution system. Therefore, the purveyor **must** provide evidence of a complete hydraulic analysis in support of the BPS design to DOH. See Section 8.2 and WAC 246-290-110(2) and (4) for a description of this requirement.

10.2.1 Hydraulic Design for the Supplying System – Normal Operating Conditions

The engineer **must** design the BPS to maintain at least 30 psi at all service connections throughout the low service, or *supplying* distribution system, under the following flow conditions (WAC 246-290-230(5)):

1. **Open System BPS**: PHD within the service area of the supplying distribution system plus supply to the BPS equal to the MDD-rate in the higher-pressure service area. If the BPS was designed to deliver a greater flow rate than the MDD-rate of the high-pressure service area under normal operating conditions, the engineer **must** use the greater flow rate to determine the capacity of the supplying system to deliver needed flow to the BPS.
2. **Closed System BPS**: PHD within the service area of the supplying distribution system plus supply to the BPS equal to the PHD in the higher-pressure service area, or the design flow rate of the BPS, whichever is greater.

10.2.2 Hydraulic Design for Supplying System: Fire Flow Conditions

The engineer **must** design the BPS to maintain at least 20 psi at ground level at all points in the low service, or *supplying* distribution system, under the following conditions:

1. **Open System BPS:** Under fire flow plus the MDD rate conditions within the supplying distribution system (WAC 246-290-230(6)), the open system BPS design should include provisions to *lock out* pump operation whenever one of the following conditions exists:
    a. Suction pressure causes the pressure at service connections along the supplying distribution system to fall below 20 psi.
    b. Suction pressure falls below 10 psi anywhere in the suction end of the BPS piping. Storage in the high service area would provide water service during the lockout period.
2. **Closed System BPS:**
    a. Under fire flow plus the MDD rate conditions within the supplying distribution system (WAC 246-290-230(6)) plus supply to the BPS equal to the PHD of the high service area.
    b. PHD within the supplying distribution system, plus supply to the BPS equal to fire flow plus the MDD rate conditions (WAC 246-290-230(6)) for the high service area.

10.3 Mechanical Design Considerations

The engineer should consider the following design issues for BPS design:

1. Pump efficiency at the operating point(s) (at the intersection of the pump curve(s) with the system head curve(s)).
2. Pump start-up and performance testing requirements.
3. Pressure rating of pump casing and end connections.
4. Horsepower requirements at full load; identify operating efficiency at full load, and specify service factor.
5. Electric motor thermal overload protection.
6. Electric supply available at the voltage, amperage, and desired phase configuration.

7. Providing backup power facilities as described in Section 7.7 and 9.5.1.
8. Potential for surge or transients (water hammer) as described in Section 8.1.8.
9. Need for treatment of pump station discharge (chlorination, for example).
10. Pipe and equipment support requirements (thrust block or other restraint).
11. Maintenance requirements for access and equipment removal and replacement.
12. Benefit of installing a piping bypass around the pumping equipment.

10.4 BPS Appurtenant Design

The engineer should consider several elements as part of the overall BPS design. See Section 10.4.1 through 10.4.7.

10.4.1 General

The design and installation of the housing for the booster pump station should:

1. Comply with applicable building and electrical codes.
2. Be secure from vandalism, trespass, and severe weather conditions.
3. Be adequately insulated.
4. Provide heating to prevent freezing during winter.
5. Provide adequate ventilation to control humidity and prevent overheating in the summer.
6. Provide adequate drainage.
7. Provide easy access for replacement or repair of equipment.

DOH also recommends the following appurtenances:

1. A sample tap on the common discharge line to aid in water quality monitoring and investigation.
2. An injection tap on the common discharge line to aid in emergency treatment.

10.4.2 Meters and Gauges

At minimum, each pump should have a standard pressure gauge on its discharge line, between the pump and the discharge check valve; a compound gauge on its suction side; and a way to meter the discharge. Larger BPSs should have recording gauges. Each BPS should also have a meter capable of measuring the total water pumped. The engineer should also consider a flow-rate indicator to monitor the performance of the pumps.

10.4.3 Valving

Pumps should have valves adequate to permit satisfactory operation, maintenance, and equipment repair. There should be isolation valves on the suction and discharge side of the booster pump. Other appurtenances include:

1. Check valves on the discharge side of each booster pump.
2. End connections for booster pumps, pressure vessels, and large equipment should have flexible flanged coupling adapters for larger units and threaded unions for smaller units. They will simplify maintenance and provide flexibility in installation.
3. Pump control valves and surge anticipation valves, as needed. They will prevent destructive hydraulic transients during normal and emergency pump start or stop.

10.4.4 Controls

The BPS should have a visible external alarm light (with a battery backup) designed to indicate pump failure or low-pressure conditions in the BPS service area. If practical, the BPS alarm system should be connected to a 24-hour operations center or an automatic signal transmitted by phone to an authorized operator. The BPS should also have a system to monitor suction pressure. It will ensure the pumps do not operate with insufficient net positive suction head, or at the expense of operating pressures in the distribution system from which they are drawing water.

10.4.5 Cross-Connection Control

When designing or installing individual service booster pumps, the engineer should recognize that the premises the pumps will serve is a **cross-connection hazard.** Under normal circumstances, the pressure on the downstream side of the booster pump is higher than system pressure. However, the check valve(s) normally provided could fail or leak, causing water from the premises to backflow through the pump and into the distribution main. This is an unavoidable or uncorrectable cross-connection situation (WAC 246-290-490(4)(e)(iii)). To prevent it from occurring, the purveyor **may** require the:

1. Water system to be protected by a backflow prevention device commensurate with the degree of hazard.
2. Water to be supplied through an approved air gap prior to being pumped.
3. Consumer to pay for the backflow prevention device, its inspection and testing.

Water that enters the consumer’s premises is “used water.” Therefore, any piping arrangement that allows pressure relief **must not** be directed back into the distribution system (WAC 246-290-490(2)(l)).

10.4.6 Pump Protection

In addition to check valves listed in Section 10.4.3, each pump motor should have protection from power supply disruptions. Such disruptions include, but are not limited to, lightning, loss of voltage, or loss of phase.

10.4.7 Piping Material

The engineer should use appropriate materials for interior BPS piping designs, such as ductile iron, steel, galvanized iron, or copper piping. PVC piping should not be used. The design should also address special anchoring or support requirements for equipment and piping.

10.5 Backup Power Facilities for Closed System Booster Pump Station

Because the service area of a closed system BPS depends entirely on the continuing operation of the BPS, the engineer **must** consider standby power facilities (WAC 246-290-420). The BPS, in effect, acts as the only source of supply and pressure for the area served. Backup or alternate power facilities should have an automatic transfer switch that starts the moment the utility power supply is interrupted. Manual transfer may be sufficient if it occurs in a reasonable period according to established operating procedures. If fire flow is required, closed system BPSs **must** have backup power unless specific reliability requirements are met (WAC 246-293-660(1)(c)).

10.6 Booster Pump Station Structural Design

The engineer **must** consider seismic risk when designing a BPS (WAC 246-290-200). See Section 13.5 for guidance on seismic design of BPSs.

10.7 Multiple Pump Design Considerations

A water system may include multiple pumps designed and operated to provide variable design flows to its service area. The configuration of a multiple pump operation can be "parallel" or in "series." The design engineer should be familiar with the procedures for sizing multiple pumps under either the parallel or series operational modes.

Parallel pump operation: The combined pump head-capacity curve is determined at the same head. Just add the capacities of the individual pump curves after they are modified to account for ordinary friction losses that occur as part of the system head-capacity curve. The point where the combined curve and the system head-capacity curve intersect yields the total capacity of the combined pumps and the modified head at which each operates. The actual total capacity is normally less than the sum of the individual capacities of each pump.

Series pump operation: The combined head-capacity curve is determined by adding the head of each pump at the same capacity (pumping rate). This mode is used to increase the head capacity of the pumping station. The combined operating head will be greater than each individual pump can provide, but not as great as their sum.

Several textbooks cover the design and selection of pumps for multiple pump operations (Heald 2002; Sanks et al. 1998; Karassick 2001; White 1998; Lobanoff and Ross 1992; Hicks and Edwards 1971).

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Chapter 11: Hydropneumatic (Pressure) Tanks

A hydropneumatic or pressure tank is any vessel containing pressurized air and water. The compressed air acts as a cushion to exert or absorb pressure as needed. Water systems use pressure tanks to:

1. To maintain water delivery within a selected pressure range while minimizing pump cycling, and
2. To absorb water hammer shocks in large capacity pumping systems. This chapter explains how to select appropriate pressure tanks.

11.0 General

Water systems use pressure tanks with well pumps and when re-pumping water (from a reservoir into a distribution system, for example). Pressure tanks make it possible to deliver water within a selected pressure range without continuously operating pumps or having the pumps start every time there is a minor call for water on the distribution system.

Pressure tanks are usually cylindrical, although other shapes are possible if they are structurally sound enough to hold pressure. These vessels usually have an internal lining to prevent corrosion. As water absorbs air, a small compressor can periodically replenish the air volume. Some pressure tanks, known as bladder tanks, have pre-charged air bladders so compressors are not necessary.

11.1 Pressure Tank Sizing Procedure

Pressure tanks are frequently the only storage facilities Group B water systems have.

When designing Group A water systems, engineers should select ground or elevated storage as described in Chapter 9. Pressure tanks are not appropriate for fire protection purposes.

The portion of pressure-tank volume that can be withdrawn between pumping cycles is not true storage. Although people frequently call this volume ***storage capacity,*** this manual refers to it as ***withdrawal capacity.***

11.1.1 Types of Pressure Tanks

Water systems may use two types of pressure tanks to protect water system pumps. Each has its own basic design procedures. ***Conventional tanks*** allow air-water contact. ***Bladder tanks*** have some type of membrane separating the air from the water.

The following sections of this chapter include tank sizing procedures and examples.

11.1.2 Conventional Tank Sizing Equations (bottom outlet)

Horizontally Oriented Tanks

Equation 11-1:

$$V_t = \frac{[(P_1 + 14.7)]}{[P_1 - P_2]} \quad \frac{15\ Q_p\ (MF)}{Nc}$$

Vertically Oriented Tanks

Equation 11-2:

$$V_t = \frac{[(P_1 + 14.7)]}{[P_1 - P_2]} \quad \frac{15\ Q_p}{Nc} + 0.0204\ D^2$$

Where:

V_t	=	Total tank volume in gallons
P_1, P_2	=	Pressures selected for water system operation in psig (not absolute pressures). **P_1** corresponds to the pump-off pressure and **P_2** to the pump-on pressure
Nc	=	Number of pump operating cycles per hour. This number is either the current DOH recommendation of six cycles per hour or a larger value that can be justified and documented by pump or motor manufacturers' warranties
Q_p	=	Pump delivery capacity in gallons per minute at the midpoint of the selected pressure range. Determine this by examining pump curves or tables. If this value is not used, the Q_p that occurs at P_2 (pump-on) **must** be used
D	=	Tank diameter in inches
MF	=	A multiplying factor related to tank diameter to ensure a six-inch water seal at the bottom of the tank. These values for several tank diameters are in Table 11-2. Use this factor only for sizing a horizontal tank

Note: *The MF is the ratio of the total tank volume, V_t, divided by the difference between the nominal volume and the volume needed to ensure a 6-inch water seal at the bottom of the tank (V_t - V_6). Because the ratios of the volumes for any tank at a given length are the same as the ratio of the tank cross-sectional areas, MF can be determined with the following equation:*

$$MF = \frac{V_t}{V_t - V_6} = \frac{A_t}{A_t - A_6}$$

Where:

A_t = The nominal cross sectional area of the horizontal tank.

$At = \pi (D^2)/4$

A_6 = The area of the bottom section of the horizontal tank that is 6-inches deep

$A_6 = (D^2/4) \cos^{-1}(1 - 12/D) - (D/2 - 6)(6D - 36)^{1/2}$

Note: *When the arccosine ($\cos^{-1}$) value is calculated in degrees, it will need to be multiplied by (π/180) to convert degrees to radians.*

11.1.3 Conventional Tank Design Procedures

Here is the procedure for using these equations:

1. Based on water system hydraulic requirements, select the operating range of pressure, P_1 (pump-off) and P_2 (pump-on), in terms of psig.
2. Select the operating cycles per hour, N_c. The value for N_c should not exceed six cycles per hour unless documented manufacturers' warranties justify larger values. For multiple pump installations, N_c may be increased if an automatic pump switchover system is installed to automatically alternate pumps. The actual increase in N_c should be justified by documented manufacturers' warranties.
3. Determine the delivery capacity, Q_p, for the midpoint of the operating pressure range [$(P_1 + P_2)/2$]. The ultimate pump capacity **must** meet system requirements at P_2 pressure (WAC 246-290-230 and 420).
   Note: *When multiple pumps will be pumping through a pressure tank, the* Q_p *can be based on the largest pump.*
4. For either vertical or horizontal tanks, select a tank diameter (in inches) that suits the space available in the pump house.
5. For a **horizontal tank**, refer to Table 11-2 for the multiplying factor, ***MF***, needed to accommodate the required water seal. The MF in this table is calculated to provide a 6-inch water seal depth above the tank invert elevation. If a **vertical tank** is to be used, the additive value for the water seal volume can be calculated directly and is already included in Equation 11-2.
6. Calculate the necessary tank volume by incorporating the parameters above into the appropriate sizing equation. If the tank selected is more than 120 gallons, it is subject to the American Society of Mechanical Engineers (ASME) code construction requirements identified in Section 11.2.
7. Check the calculated volume requirement with any commercial tank size table (Table 11-1, for example) to see if a tank that meets the necessary volume at the selected diameter is available. If a tank that provides the necessary volume at the diameter selected is not available, or cannot be fabricated, select another tank diameter and repeat the sizing calculations until the design is satisfied. This may also be necessary if the pump house layout will not accommodate the length needed.

Example 11-1

1. Assume a small water system with the following:
   a. 50 connections.
   b. PHD (from water system meter information) = 103 gpm.
   c. Well capacity is 60 gpm.
   d. Ground-level storage.
   e. Booster pump and pressure tank used to draw from storage.
   f. Desired pressure range is 40/60 psig (minimum/maximum).
   g. Booster pump capacity is 96 gpm at 50 psig $[(P_1 + P_2)/2]$ as determined from the pump curve or table.
2. A horizontal cylindrical tank with bottom outlet will be used. The pump cycling will be limited to no more than six cycles per hour.
3. Minimum water seal of 6 inches is required.
4. Pertinent data summarized:

   $\mathbf{P_1 = 60}$ $\quad$ $\mathbf{P_2 = 40}$ $\quad$ $\mathbf{Q_p = 96}$ $\quad$ $\mathbf{N_c = 6}$

5. Select a trial tank diameter of 42 inches. Using Table 11-2, the multiplying factor, MF, is 1.10 (by interpolation between the 36-inch and 48-inch tank sizes).
6. Substituting these values in the horizontal tank equation, Equation 11-1,

$$\mathbf{V_t} = \frac{[(P_1 + 14.7)]}{[P_1 - P_2]} \quad \frac{15\,(Q_p)(MF)}{N_c}$$

$$\mathbf{V_t} = \frac{[(60 + 14.7)]}{[20]} \quad \frac{15\,(96)\,(1.10)}{6}$$

$$\mathbf{V_t} = \mathbf{986\ Gallons}$$

   This is the minimum volume that will satisfy the 6-inch seal-depth requirement for a 42-inch diameter vessel. The tank selected from commercial charts will need to be equal to or greater than this volume.

7. A commercial tank table (see Table 11-1 for this example) shows there is a 42-inch tank with a volume of 965 gallons. This volume is close to the required 986 gallons, but it will not give a 6-inch water seal under the operating conditions stipulated. Therefore, if a tank with a 42-inch diameter is to be used, the next larger tank of 1,037 gallons is the one to select.

Note: *If a 48-inch diameter tank had been selected, a minimum volume of 968 gallons would be calculated. For this example, Table 11-1 shows a 994-gallon tank is available and acceptable. Be sure to notice that the 48-inch tank would be about four feet shorter than the 42-inch tank. That may be an important consideration when placing a tank in limited space.*

11.1.4 Bladder Tank Sizing

The procedure for selecting or sizing bladder tanks differs from that used for conventional tanks. Bladder tank sizing depends on the number of "selected-size" tanks needed to provide pump protection. Bladder tanks are assumed to be pre-charged with air to a pressure of 5 psi below the low operating (cut-on) pressure for the system. Engineers need to call out this stipulation in the design specifications.

11.1.5 Bladder Tank Sizing Equations

Equation 11-3:

$$T_s \geq \frac{(R)(Q_p)}{(N_c)(V_B)}$$

Where:

$$\boldsymbol{R} = \frac{15(P_1 + 14.7)(P_2 + 14.7)}{(P_1 - P_2)(P_2 + 9.7)}$$

The terms in the above equations are the same as those above for conventional pressure tank design. The new terms, $\boldsymbol{V_B}$ and $\boldsymbol{T_s}$, are defined as:

$\boldsymbol{V_B}$ = The volume of an individual bladder tank in gallons

$\mathbf{T_s}$ = The number of bladder tanks of size $\mathbf{V_B}$

11.1.6 Bladder Tank Design Procedure

1. Select $\boldsymbol{P_1}$, $\boldsymbol{P_2}$, $\boldsymbol{N_c}$, and $\boldsymbol{Q_p}$ as explained in items 1, 2, and 3 of the conventional tank procedure.
2. Select an appropriate volume, $\boldsymbol{V_B}$, to be used for each bladder tank. This volume should be available from bladder tank manufacturers, but **must** not exceed 120 gallons.
3. Calculate the value of ***R***. For convenience, Table 11-3 gives ***R***-values for several commonly used pressure ranges.
4. Use Equation 11.3:

   $$T_s \geq \frac{(R)(Q_p)}{(N_c)(V_B)}$$

5. Round up the value determined in Step 4 to the nearest whole number. This is the number of tanks, each with the selected volume, V_B , to be used for pump protection.

Example 11-2:

For a mid-pressure range pumping rate, Q_p, of 100 gpm, a selected cycling of six cycles per hour, a bladder tank volume of 80 gallons, and a selected pressure range of 40/60, the number of 80-gallon tanks required is determined as follows:

1. $Q_p = 100$; $N = 6$; $V_B = 80$
2. Using Table 11-2 for $P_2/P_1 = 40/60$, $R = 61.7$
3. Using Equation 11-3:

$$T_s > \frac{(R)(Q_p)}{(N_c)(V_B)}$$

$$T_s > \frac{(61.7)(100)}{(6)(80)} = 12.8$$

4. Select 13 bladder tanks, each with an 80-gallon volume pre-charged to 35 psi (5 psi below cut-in pressure), for pump protection.

11.2 Department of Labor and Industries Requirements

Many pressure tanks typically used in water systems are "unfired pressure vessels" that must comply with chapter 70.79 RCW and the Department of Labor and Industries' (L&I) regulation (chapter 296-104 WAC). These regulations require all pressure tanks more than 5 cubic feet (37.5 gallons) in volume to be constructed according to the latest edition of ASME specifications code (RCW 70.79.080). While all pressure tanks used by water systems **must** meet the construction and installation requirements of chapter 296-104 WAC, they are exempt from routine L&I inspections and fees (RCW 70.79.090(6)).

All pressure tanks **must** be protected against over-pressurization with a safety valve, such as a properly sized and installed ASME-approved pressure relief valve (PRV) (WAC 296-104-316). The PRV **must** be installed on top of the tank or on outlet piping as close as possible to the vessel without any valves between the PRV and the pressure tank (WAC 296-104-235). The "set" pressure of the PRV must not exceed the design pressure of the vessel.

The maximum allowable working pressure for a tank is on the nameplate attached to the tank. For non-standard pressure vessels, engineers can determine the maximum allowable working pressure with the L&I formula in WAC 296-104-405. A properly sized ASME PRV should have a relieving capacity that will prevent pressure in the vessel from rising more than 10 percent or 3 psi above the maximum design set pressure, whichever is greater, but never more than the maximum allowable working pressure for the hydropneumatic tank.

11.3 Locating Pressure Tanks

Pressure tanks should be located above normal ground surface and be completely housed. At least 18 inches of clearance, and usually more, **must** be provided around the tanks for proper inspection, maintenance, and repair access (WAC 296-104-260). In some cases, it may not be practical to provide this much clearance all the way around a pressure tank. Therefore, L&I developed a *Boiler/Pressure Vessel Clearance Variance Request* form (F620-041-000). It is available from the L&I Boiler/Pressure Vessel Web site in Appendix C.

11.4 Piping

Pressure tanks should have bypass piping to permit the water system to operate while it is being repaired or painted. Sampling taps should be provided before and after the pressure tank.

11.5 Pressure Tank Appurtenances

The following is needed to maintain the proper balance of air-to-water volume in the pressure tank at all times:

- An automatic pressure release valve.
- Mechanical means for adding air, including an air filter.
- Sight glass or other tank level indicator.
- Drain, pressure gauge and pressure switch.
- An access hatch. Where practical, the access hatch should be 24 inches in diameter. To allow operators to inspect the interior of the vessels, access hatches **must** be installed with a clearance of at least 5 feet between the hatches and any adjacent structures (WAC 296-104-260).

11.6 Hydropneumatic Tank Sizing with Cycle Stop Valves

A device called the cycle stop valve (CSV) was developed to maintain and control the pressure in a distribution system. Essentially a modified pressure-reducing valve, it maintains a constant downstream pressure over a wide range of flows. Depending on the model used, the CSV will stop pump operation at a pre-set threshold flow of 1 gpm or 5 gpm. At flows higher than that, the valve will open or close in response to water system demands for water while the pump operates continuously.

A water system using a CSV still needs a pressure tank. However, the criteria used to size pressure tanks with CSVs differ from those used to size conventional pressure tanks. Pump motor over-cycling protection relates to the length of time the tank's stored water is used when service demands go from less than, to above the CSV set point (either 1 gpm or 5 gpm). Therefore, tanks for water systems using CSVs will be smaller than those required by conventional systems. Recommendations for sizing pressure tanks with CSVs are in Appendix B.

Table 11-1: Pressure Tank Dimensions*

Dimensions, Capacities and Tappings							
		Dimensions, Inches			Tappings, FPT		
Tank Model Number	Capacity Gallons	Outside Diameter A	Shell Length B	Approximate Overall Length C	Relief R	Blowdown S	Water In & Out W
144	36	14	48	58	3/4		1
145	44	14	60	70	3/4		1
164	48	16	48	59	3/4		1
165	58	16	60	71	3/4		1
166	69	16	72	83	3/4		1
184	62	18	48	60	3/4		1-1/4
185	75	18	60	72	3/4		1-1/4
186	88	18	72	84	3/4		1-1/4
204	77	20	48	62	1		1-1/4
205	93	20	60	74	1		1-1/4
206	109	20	72	86	1		1-1/4
244	113	24	48	64	1		1-1/4
245	137	24	60	76	1		1-1/4
246	160	24	72	88	1		1-1/4
247	184	24	84	100	1		1-1/4
304	186	30	48	67	1		2
305	223	30	60	79	1		2
306	260	30	72	91	1		2
307	296	30	84	103	1		2
308	333	30	96	115	1		2
309	370	30	108	127	1		2
365	330	36	60	82	1		2
366	383	36	72	94	1		2
367	436	36	84	106	1		2
368	489	36	96	118	1		2
369	542	36	108	130	1		2
3610	594	36	120	142	1		2
426	533	42	72	96	1-1/4	2	2
427	605	42	84	108	1-1/4	2	2
428	677	42	96	120	1-1/4	2	2
429	749	42	108	132	1-1/4	2	2
4210	821	42	120	144	1-1/4	2	2
4211	893	42	132	156	1-1/4	2	2
4212	965	42	144	168	1-1/4	2	2
4213	1037	42	156	180	1-1/4	2	2
4214	1110	42	168	192	1-1/4	2	2
486	712	48	72	100	1-1/4	2	3
487	806	48	84	112	1-1/4	2	3
488	900	48	96	124	1-1/4	2	3
489	994	48	108	135	1-1/4	2	3
4810	1089	48	120	148	1-1/4	2	3
4811	1183	48	132	160	1-1/4	2	3
4812	1277	48	144	172	1-1/4	2	3
4813	1371	48	156	184	1-1/4	2	3
4814	1465	48	168	196	1-1/4	2	3
548	1160	54	96	126	1-1/2	2	3
5410	1398	54	120	150	1-1/2	2	3
5411	1517	54	132	162	1-1/2	2	3
5412	1636	54	144	174	1-1/2	2	3
5413	1755	54	156	186	1-1/2	2	3
5414	1874	54	168	198	1-1/2	2	3

Dimensions, Capacities and Tappings							
		Dimensions, Inches			Tappings, FPT		
Tank Model Number	**Capacity Gallons**	**Outside Diameter**	**Shell Length**	**Approximate Overall Length**	**Relief**	**Blowdown**	**Water In & Out**
5415	1993	54	180	210	1-1/2	2	3
5416	2112	54	192	222	1-1/2	2	3
6010	1750	60	120	154	1-1/2	2	3
6012	2044	60	144	178	1-1/2	2	3
6014	2338	60	168	202	1-1/2	2	3
6016	2632	60	192	226	1-1/2	2	3
7210	2609	72	120	160	1-1/2	3	4
7212	3032	72	144	184	1-1/2	3	4
7214	3455	72	168	208	1-1/2	3	4
7216	3878	72	192	232	1-1/2	3	4
Above data is based on use of Elliptical Heads with 2" max SF.							

* Table furnished for example only. Any commercial table may be used.

Table 11-2: Multiplying Factors that Ensure a 6-inch Water Seal Depth in a Horizontal Pressure Tank

(Use with Equation 11-1)

Tank Nominal Diameter, inches	Multiplying Factor $MF = V_t/(V_t - V_6)$
12	2.00
16	1.52
20	1.34
24	1.24
30	1.17
36	1.12
48	1.08
54	1.06
60	1.05
72	1.04
84	1.03
96	1.03
120	1.02

Note: Use *linear interpolation to determine MF values for diameters between those shown. Use an MF of 1.02 for horizontal tanks with diameters of 120 inches, or more.*

Table 11-3: R Values for Various Maximum and Minimum Pressure Tank Ranges

	P_1 maximum pressure (gauge)			
P_2 minimum pressure (gauge)	**55 psi**	**60 psi**	**65 psi**	**70 psi**
35 psi	58.1	49.8	44.3	40.4
40 psi	76.7	61.7	52.6	46.6
45 psi	114.1	81.5	65.2	55.5
50 psi	226.6	121.4	86.4	68.8

Chapter 12: Water Quality and Treatment

This chapter provides guidance on selecting treatment alternatives. It clarifies the scope and content of required treatment design submittals and includes general information on water treatment topics. The references at the end of this chapter provide more details on specific topics.

12.0 Applicability

Design engineers should be familiar with the chapter 246-290 WAC. The WAC contains requirements for treatment facility design and operation. It does not address all possible treatment alternatives, so design engineers should review DOH policies for more information. DOH policies are available from the Web site listed in Appendix A.

12.1 Submittal Requirements

Engineers must submit the following design elements for most new, expanded, or modified treatment facilities to DOH for approval:

- Analysis of alternatives
- Pre-design studies
- Project reports
- Construction documents
- Construction completion reports

If the design engineer and DOH agree that it will not adversely affect the overall safety and reliability of the project, the engineer may omit or reduce the scope of some project elements. Specific regulatory requirements and the general scope of these basic project elements follow.

12.2 Analysis of Alternatives

Purveyors required to have a water system plan **must** have a current, approved water system plan that adequately addresses the proposed treatment project before an engineer analyzes the treatment project alternatives (WAC 246-290-110(3)). The engineer **must** evaluate all appropriate and applicable alternatives before selecting the particular treatment system to design. The engineer **must** justify the selected alternatives in project reports submitted to DOH for approval (WAC 246-290-110(4)(c)).

The engineer should follow industry guidance by including the following items in the analysis of alternatives (AWWA 1998a; Kawamura 2000a)):

1. Current and known future finished drinking water requirements.
2. Raw-water characteristics.
3. Current and anticipated future capacity needs.

4. Existing required water system components.
5. Operational flexibility.
6. Availability of skilled operators.
7. Waste disposal and management.
8. Cost effectiveness.

This chapter includes tables designers can use to select treatment alternatives to evaluate. Designers should use these tables for preliminary screening of potential treatment alternatives prior to in-depth analysis.

Water systems may not use point-of-use (POU) or point-of-entry (POE) devices to comply with water quality standards. DOH limits the use of POU and POE treatment because their use is incompatible with the existing regulatory requirements (WSDOH 2007). A limited exception to this restriction is a single-connection water system that uses one treatment device to treat all the water entering a building.

12.2.1 Finished Drinking Water Requirements

Regulations and customer concerns about health and aesthetic qualities normally drive finished drinking water standards (such as treatment techniques and maximum contaminant levels (MCLs)). Requirements and aesthetic guidelines are in current technical guides, as well as the federal rules and chapter 246-290 WAC.

Treatment used to meet minimum requirements may not always meet the expectations of the owner or water system customers. Therefore, the design engineer should discuss community acceptance issues and water quality goals with the owner before beginning preliminary screening of treatment alternatives. Some purveyors and engineers base these discussions on community meetings or customer surveys on water quality preferences.

12.2.2 Raw Water Data Considerations

Source water and finished water quality objectives form the primary basis for selecting treatment process alternatives. The extent and availability of raw water data may affect preliminary screening of alternatives and the duration of the pilot study.

Surface water sources and groundwater under the direct influence of surface water (GWI) can experience rapid and seasonal changes in water quality. The source water characterization should account for these water quality variations. Therefore, the design engineer should have at least one-year of water quality information before making a preliminary determination of a treatment method for most surface water sources.

Engineers can use a relatively short-term sampling program to characterize groundwater wells and other sources not subject to significant water quality variability throughout the year (springs not influenced by surface water).

DOH recommends that the design engineer contact a DOH regional engineer (see Table 1.1):

- **If a water system must provide corrosion control for copper or lead**. We can give you applicable water quality sampling parameters. The references at the end of this chapter include corrosion control applications (pipe deterioration, asbestos, and aesthetics).
- **To discuss initial monitoring plans**. If extensive data is unavailable, the design engineer should collect the necessary data, consider multiple alternatives, or conduct an extended pilot study.

12.2.3 Waste Handling

The Department of Ecology regulates waste-product discharge, such as sludge, backwash water discharged to waste, ion exchange waste streams, and membrane reject water. Water systems developing water treatment proposals should evaluate waste-product issues early because they could significantly affect the cost or feasibility of a proposed approach or technology.

Design engineers should remember the following constraints when analyzing treatment alternatives.

- Surface water plants with rapid-rate filtration that recycle process water **must** comply with filter backwash recycling requirements (WAC 246-290-660(4)).
- Surface water plants **must** introduce process-water waste-streams (such as filter backwash and discharge from sedimentation basins) upstream of all treatment processes, including coagulant addition.
- Surface water plants **must** hydraulically control recycle streams to avoid exceeding the operating capacity of the plant.

DOH advises operating facilities to monitor their backwash water quality for coliform bacteria, total organic carbon (particularly if algae are in backwash water lagoons), and turbidity or particle counts. They can use this information to evaluate maximum recycle rates or decide whether to recycle at all.

The Department of Ecology issued a National Pollutant Discharge Elimination System (NPDES) general permit for water treatment plants with a capacity of 50,000 gpd (about 35 gpm) or more that discharge flow—or could discharge flow—into surface water. This permit restricts the pH, chlorine residual and settleable solids in the discharge water. Eligible facilities **must** apply for coverage. Information on the NPDES permit and related requirements is online at http://www.ecy.wa.gov/programs/wq/wtp/index.html The NPDES general permit does not cover facilities that:

- Use ion exchange.
- Use reverse osmosis.
- Use slow sand filtration.
- Discharge to land or a sewage treatment plant.

The Department of Ecology regulates waste discharges from ion exchange and reverse-osmosis treatment facilities separately. The process-water discharge requirements for these types of facilities are in the *Fact Sheet for NPDES General Permit: Water Treatment Plants* (WSDOE 2004), available online at http://www.ecy.wa.gov/programs/wq/wtp/index.html (click on "fact sheet"). Engineers should contact the Department of Ecology early in the design process to determine restrictions on waste discharges that may affect the feasibility and cost of a water treatment project.

12.2.4 Operations and Maintenance Considerations

During the analysis of treatment alternatives, the design engineer should consider:

- **Expected operational capability of the water system.** This depends on size. Smaller water systems often can't provide the same level of operational capability as large water systems. Engineers should select technology appropriate for the anticipated level of expertise and time the water system will have to operate the treatment facility.
- **Operator certification.** Water systems **must** be able to meet certification requirements that apply to the proposed treatment technology (WAC 246-292-050). The design engineer should identify the operator certification level for any proposed treatment facility.
- **Satellite management.** An approved satellite system management agency **must** own or operate new water systems, if one is available (WAC 246-290-035). DOH also advises existing water systems to use satellite management agencies, especially if they don't have adequate staff to operate a new or expanded treatment facility.

12.2.5 Preliminary Cost Comparisons

Estimated capital and annual operating costs **must** be in the project report for any proposed treatment project (WAC 246-290-110). Preliminary cost estimates should have the detail and accuracy purveyors need to make decisions about treatment system alternatives. In general, preliminary construction cost estimates are plus-or-minus 30 percent accurate (AWWA 1998b).

Capital costs: Location, site constraints, water system hydraulics and raw-water quality all affect capital costs. They can vary significantly from facility to facility. Engineers can sometimes use cost curves to develop preliminary construction costs for specific treatment processes and then adjust them for inflation and local condition. If you base capital cost estimates on cost curves, you should reflect other variable project costs and update them as soon as adequate data are available. Engineers can also use price quotes from equipment manufacturers, local construction experience, and information from similar projects to develop preliminary construction costs.

If the preliminary cost of two or more alternatives is similar, the design engineer should break the cost components down to provide specific justification for the selected alternative(s). In some cases, the design engineer may find a level of uncertainty that warrants additional data collection or a comparative pilot study.

Operations and maintenance costs: A water treatment facility's operations and maintenance (O&M) costs include labor, power, maintenance, repair, supplies, and services. Engineers can prepare preliminary O&M cost estimates with methods similar to those used for construction costs. However, lack of published data may make detailed component cost assessments necessary to evaluate alternative treatment methods for small water systems.

12.3 Pre-design Studies

The engineer **must** prepare a pre-design study to evaluate treatment alternatives (WAC 246-290-250). You can conduct pre-design studies at the desktop, bench-scale, and pilot-scale levels.

Desktop studies involve reviewing detailed water quality data, guidance documents, technical publications, and other information to select a treatment approach for full-scale design. Water systems can only use these studies to analyze corrosion control alternatives and a few other treatment processes. Desktop studies usually require significant amounts of water quality data to guide the selection of the most appropriate treatment alternatives.

Bench-scale studies include jar testing to identify an initial coagulant dose, initial chemical dosages for iron and manganese sequestering, and estimates of disinfection demand and decay.

Pilot-scale studies often follow bench-scale studies so engineers can identify design parameters and decide how reliable a treatment process will be over the range of source-water quality conditions.

12.3.1 Pilot Studies

To ensure treated water will meet water quality standards, engineers **must** conduct pilot studies before they design or modify treatment facilities (WAC 246-290-250). The limited exceptions to this requirement are simple disinfection technologies for very small groundwater sources (< 3,300 population). Large water systems should perform bench-scale tests on proposed disinfection methods to evaluate the potential of generating regulated disinfection byproducts.

Pilot-studies attempt to replicate the operating conditions and treatment results expected at full scale as closely as possible. Pilot plants are scaled-down versions of a proposed process, and may be skid or trailer mounted. Engineers use pilot plant testing to:

- Ensure treatment is effective.
- Determine final design parameters.
- Estimate construction and operation costs.

Some water systems are so small that the capacity of the pilot is equal to or greater than the capacity of the full-scale treatment unit. In that case, the purveyor and designer should approach the pilot facility design as if it will be a permanent facility in the future. However, final acceptance of the facility depends on a successful demonstration as determined by an approved pilot-study plan report. The significant risk associated with designing a pilot to full-scale is that treatment efficiency or operation costs will not match pre-design expectations, and either major modification or complete abandonment of the approach may be required. Submittals for full-scale pilot testing should identify actions the engineer will take if it is necessary to make major modifications or abandon the project.

Water systems may use water from full-scale pilot tests for public consumption if they meet **all** of the following conditions:

1. Source capacity limitations on an existing water system do not provide adequate source capacity for the combined demand of the existing customers and the pilot study.
2. Application of the treatment device does not increase the level of any primary water quality contaminant with an established MCL.
3. Start-up, testing, and operation procedures are approved as part of a pilot-study plan.
4. The treatment system technology:
    a. Received DOH approval for demonstrating adequate removal of specific contaminants.
    b. Is an approved alternative filtration technology for surface water applications.
    c. Is constructed of components that do not leach or otherwise add substances to the finished water as demonstrated through third party testing that meets the requirements of ANSI/NSF Standard 61.

DOH *may waive* the pilot study for:

- Identical treatment processes on nearly identical source waters, such as reverse osmosis on well-circulated seawater.
- Some groundwater treatment projects that use an identical treatment process and have similar water quality data. Analogous system criteria for groundwater include:
    - Less than 5 percent variability of raw water pH.
    - 5 percent variability of raw water total organic carbon (applies if greater than 2 mg/L).
    - 20 percent variability of raw water primary and secondary IOCs.

There are no analogous criteria for any surface water treatment technologies. Analogous surface water sources are rare. However, in some isolated cases, a design engineer may justify limited or reduced piloting for surface water treatment. DOH anticipates this will include only water systems with similar withdrawal points from the same water source.

Equipment for proprietary processes is usually so specialized that pilot testing results are unique to a specific equipment design. For example, differences in low-pressure membrane filtration make it impractical to transfer pilot results from one proprietary design to another. These differences include:

- **Driving forces**. Both pressure and vacuum filtration are used.
- **Flow path**. Inside-out or outside-in relative to the membrane fiber.
- **Fiber design**. Materials, pore size, oxidant tolerance, surface charge, wall thickness, internal diameter, and external diameter.
- **Module design**. Number of fibers per module, fiber-packing density, potting material, and connection to manifolds.
- **Process design**. Raw water quality limitations, pretreatment, back-flush frequency, chemicals used for water treatment and cleaning.

There are similar constraints on data transfer for other proprietary technologies.

Sections 12.3.2 through 12.3.4 discuss the recommended pilot study duration, content of a study plan, and final study report.

12.3.2 Pilot Study Duration

Pilot studies should be long enough to demonstrate the effectiveness, stability, and reliability of the proposed treatment system. Pilot testing of surface water treatment **must** capture seasonal changes in water quality, such as fluctuations in raw water alkalinity, temperature, pH, color, turbidity, tastes, odors, and organic matter (WAC 246-290-676(3)). The testing should include the period of most challenging water quality for the piloted treatment technology. Pilot studies often are shorter for groundwater than surface water because groundwater quality is usually more stable.

The number of samples collected and study duration can vary widely depending on the type of source, amount of historical data, water quality, and the proposed treatment technology (Logsdon et al. 1996; Ford et al. 2001; AWWA 1998c). In some cases, engineers can use bench-scale testing to determine the initial operational parameters for pilot testing and possibly decrease the duration of the pilot study. See Table 12-1 for guidance on the duration and objectives of pilot studies for a variety of treatment processes.

12.3.3 Pilot Study Plan (Protocol)

A pilot study plan is necessary to establish an implementation strategy for evaluating a proposed treatment alternative, or alternatives (WAC 246-290-676(3)(b)). Pilot studies require detailed protocols. The pilot-study plan establishes pilot study goals, monitoring programs, operational requirements, equipment needs, layout, and costs. Several of the elements discussed on the following pages are appropriate for desktop or bench-scale studies. Engineers should address them in the protocol they submit to DOH for approval.

Pilot Study Goals: Engineers should use the following goals to determine the scope of a pilot study and for pilot study planning and operational decisions:

1. Determine the operational feasibility of a selected technology.
2. Establish full-scale water-treatment design criteria.
3. Develop more refined cost estimates.
4. Provide hands-on operator training for water system personnel.
5. Determine projected hydraulic impacts on the water system.
6. Select an appropriate treatment technology.
7. Determine waste disposal constraints.

Monitoring Program: Pilot study monitoring programs vary significantly depending on the treatment device, finished water requirements, and the specific contaminants in the source water. Engineers can use Table 12-1 to develop monitoring programs for the treatment technologies listed. For additional guidance, call your DOH regional engineer (see Table 1-1).

Most pilot study monitoring programs should include:

1. Water quality parameters.
2. Monitoring frequency for each parameter.
3. Monitoring equipment and calibration standards.
4. Personnel or outside laboratories responsible for monitoring activities.

Equipment Needs, Layout, and Calculations: The pilot study should include a schematic of the process or processes under consideration and the detailed drawings necessary to construct the pilot facilities. The schematic and the pilot facility design are integral to the overall project design and should include unit processes, pipe sizes, pipe connections, flow direction, chemicals and application points, monitoring points, flow-control devices, monitoring equipment or gauges, and various process elements (such as intakes, pumps and blowers). Special hydraulic considerations (such as dynamic similitude) and equipment specifications should be in a brief narrative or outline along with all supporting calculations.

Operational Requirements: Pilot study plans should identify the operational requirements necessary to ensure water system personnel understand their role and responsibility to provide routine O&M and data collection. DOH recommends that the design engineer prepare a schedule to clarify routine pilot study activities for water system personnel and others that may be involved with the study.

Pilot Study Costs: Engineers should develop equipment rental, testing, and operation costs as part of the pilot study plan. Engineers can estimate these costs after they develop the goals, duration, and monitoring program for the pilot study.

Table 12-1: Pilot Study Duration and Objectives

Treatment	Purpose	Minimum Recommended Duration	Objectives	References
Rapid Rate Filtration	Surface Water	6-12 months[1]	Coagulant dose(s), polymer dose(s), sufficient alkalinity, sedimentation rate, hydraulic loading rate, backwash parameters, disinfection byproduct (DBP) precursor removal, finished water quality.	Kawamura 2000a; Logsdon et al. 1996
Slow Sand Filtration	Surface Water	12 months	Pretreatment requirements, ripening period, run length, filter loading rate, sand type, finished water quality.	WSDOH 2003b; Hendricks et al. 1991
Diatomaceous Earth (DE) Filtration	Surface Water	1-4 months	Pretreatment requirements, pre-coat rate, filter media grade, screen size, body feed rate, run length, finished water quality.	WSDOH 2003b; AWWA 1999
Membrane Filtration	Surface Water	4-7 months	Pretreatment requirements, flux rate and stability, back flush parameters, chemical dose(s), cleaning frequency, fiber breakage, DBP precursor removal, finished water quality.	Freeman et al. 2006; USEPA 2005
Adsorption	DBP precursors, IOCs, VOCs, SOCs	6-12 months[2]	Run length, hydraulic loading rate, empty bed contact time, finished water quality.	Ford et al. 2001; Cummings and Summers 1994; Westerhoff et al. 2003
Ion Exchange	IOCs	2-12 months	Regeneration frequency, leakage, resin stability, pH/corrosion control, finished water quality.	Liang et al. 1999; Clifford and Liu 1993
Oxidation/Filtration	IOCs	1-6 weeks	Oxidant demand and dose, coagulant dose, hydraulic loading rate, filter run length, finished water quality.	Gehling et al. 2003; HDR 2001
Reverse Osmosis	Desalination	2-7 months	Pretreatment required, flux rate and stability, back flush parameters, chemical dose(s), cleaning frequency, finished water quality.	Kumar et al. 2006; USEPA 2005

Notes:

1. Engineers can consider a series of multiple week pilot studies instead of operating a full-time pilot plant.
2. Engineers can decrease the pilot test period to a few weeks if rapid small-scale column tests (RSSCTs) are used.

12.3.4 Pilot Study Report

Engineers **must** prepare a pilot study report that evaluates pilot-study data and determines whether the treatment option is feasible for full-scale implementation (WAC 246-290-250 and 676(3)). If the proposed treatment is feasible, the pilot report **must** identify the design parameters for the full-scale treatment facility (WAC 246-290-110).

General pilot-study evaluation criteria include:

1. Tabular data for each measured parameter.
2. Graphical data showing relationships between measured parameters.
3. Narrative on the relationships between measured parameters.
4. Cost projections for full-scale operation (yearly, monthly, and per customer).
5. Final design and operational parameters.
6. Recommendations for full-scale implementation.
7. Comparison of recommended design and operational parameters to design goals, water quality goals, and other performance benchmarks.

For long-term pilot studies, DOH recommends interim reports throughout the study. The interim report findings may determine if the pilot study should continue or end in lieu of other technology.

12.4 Project Report and Final Design Considerations

DOH **must** approve project reports before the purveyor installs any new or expanded treatment facilities (WAC 246-290-110). The engineer should submit a final project report for treatment facilities before submitting construction documents. Project reports for treatment facilities should reference all planning, design, and applicable pilot study reports for the proposed facility. They **must** include:

- Detailed design criteria and calculations to support the proposed treatment process, process control, and process utilities.
- Proposed methods and schedules for start-up, testing, and operating the completed treatment facility.

See Chapter 2 for guidance on preparing project reports.

12.4.1 Planning Issues

Project reports for treatment facilities **must** reference or briefly narrate applicable planning and capacity issues (chapter 246-290 WAC). If a water system must have a water system plan, DOH staff will not review a project report unless there is a current, approved water system plan that adequately addresses the proposed treatment project (WAC 246-290-110(3)).

12.4.2 Design Criteria and Facility Design

Project reports **must** include design criteria for all major treatment-facility project elements (WAC 246-290-110(4)(h)). Engineers may find design criteria for treatment facilities in a variety of sources, including:

- Water system plan.
- Pilot study plan.
- Pilot study report.
- Reference texts and journals.
- Federal, state, or local standards.

Project reports for treatment facilities should include the following:

- **Process design concepts and calculations:** DOH expects the engineer to provide a detailed narrative of design concepts, design calculations, and supporting information for the treatment process(es), process piping and equipment, process control, and waste disposal.
- **Other project design elements:** The design engineer should outline the general design aspects, such as siting issues, ingress or egress access, roads, sidewalks, parking, earthwork, drainage facilities, building layout and design, special structural requirements or constraints, heating, ventilation, fire suppression features, general utilities, electrical supply, and safety.
- **Cost and financing.** The engineer should include construction cost estimates, O&M cost estimates, and the proposed financing method(s). At this stage, the accuracy of the projected cost depends on how well the construction documents are completed, but should be within 10 percent of the actual cost (AWWA 1998b). The engineer should identify the cost-estimation method and compare the final cost estimates to the estimates in the financial program of the water system plan.

12.4.3 Start-up, Testing and Operations

Treatment facility submittals **must** include proposed methods and schedules for start-up, testing and operations (WAC 246-290-110(4)(h) and 120(4)). Detailed operational requirements for facilities treating surface water or a GWI source are in WAC 246-290-654(5).

Start-up and Testing Requirements
The start-up and testing of a treatment plant is a complex operation. Project reports **must** include proposed methods and schedules for start-up and testing (WAC 246-290-110(4)(h)). Schedules should include the anticipated start-up date and proposed testing duration. Methods should identify specific standards and the persons involved. The methods and schedules can be general in the project report and refined in the construction documents.

Construction documents **must** include detailed start-up and testing procedures (WAC 246-290-120(4)). The water system should operate the completed project for at least a few days before serving water to the public. Testing criteria and procedures include:

- Testing duration.
- Testing constraints. For example, a limitation on the disposal of treated water before construction is complete.

The specifications should identify the persons involved in start-up and testing and their specific roles:

- Engineers
- Operators
- Contractors
- Manufacturer representatives
- Regulatory agencies

The engineer **must** submit a signed *Construction Completion Report Form* (DOH 331-121) to DOH before the purveyor can use the project to supply water to the public (WAC 246-290-120(5)). See Section 12.6 and Chapter 14 for additional start-up and testing requirements.

Operations Requirements
Project reports for treatment facilities **must** address operation of the completed project (WAC 246-290-110(4)(h)). At this stage, the design engineer should identify the organization or people responsible for operating the finished facility and their required qualifications.

The engineer **must** prepare a detailed Operations Program for a water treatment facility treating a surface water or GWI source (WAC 246-290-654(5)). An Operations Program, sometimes called an operations plan or an O&M manual, is a comprehensive document operators use to operate their facility. It frequently summarizes information in O&M manuals from equipment suppliers.

The purpose of the Operations Program is to help water system personnel produce optimally filtered water quality. As such, it should identify specific, quantifiable optimization goals. Engineers can use the following to develop treatment optimization goals:

- DOH Treatment Optimization Program
- EPA Composite Correction Program
- AWWA-EPA Partnership for Safe Water
- AWWA Standard G100: Water Treatment Plant Operation and Management

At a minimum, the Operations Program **must** describe:

- Coagulation control procedures (when a coagulant is used).
- Procedures used to determine chemical rates.
- Operations and maintenance for each unit process.
- Treatment plant performance monitoring.
- Laboratory procedures.
- Reliability features.
- Emergency response plans, especially for treatment process failures and watershed emergencies.

The following items should also be included:

- An overall schematic of the treatment process.
- Process and instrumentation diagrams for the treatment facility.
- Control loop descriptions.

DOH may require the engineer to submit the Operations Program for new, expanded, or modified treatment facilities. Often, the information needed to complete the Operations Program for these facilities is not available until after construction starts. For DOH approval, the engineer may have to submit the Operations Program before construction is complete.

When developing the Operations Program, the engineer should remember that water system staff will have to update and modify it to reflect their current water treatment practices.

Training Requirements
The project report should specify applicable operator training requirements, specific training the equipment supplier(s) will provide, and related schedules. The final Operations Program and equipment-specific operations and maintenance manuals should be available during the operator training sessions.

12.4.4 Treatment System Reliability

Engineers **must** design water treatment facilities to meet minimum water quality standards **at all times**, except where otherwise noted (WAC 246-290-420(1)). “Treatment reliability” means the failure of any single component will not prevent a treatment facility from meeting drinking water standards. Information on treatment-process reliability is in the Preface of this manual and other design references (AWWA 1998d; Ten State Standards 2007).

Surface water treatment: Reliability is especially important when treating contaminants with acute health effects (surface water, groundwater requiring disinfection and nitrate). Surface water treatment plants **must** have certain reliability features including, but not limited to:

- Alarm devices for critical process components, including automatic plant shutdown.
- Standby equipment, such as chemical feed pumps, to provide continuous operation of coagulation and disinfection.
- Multiple filter units that provide redundant capacity when filters are taken out of service (WAC 246-290-678).

Alarms play a critical role in process control, especially when surface water treatment facilities operate without staff present. Therefore, project reports **must** describe proposed alarms and their settings (WAC 246-290-110(h)). Critical alarms include those for coagulation, filtration, and disinfection.

Table 12-2: Staffing Guidelines for Surface Water Treatment Facilities

	Minimum Daily Operator Guidelines	
Treatment Technology	**Comprehensive Automation [1]**	**Limited Automation [2]**
Conventional Filtration	6 to 8 hours	Continuous
Direct Filtration	4 to 5 hours	Continuous
Diatomaceous Earth Filtration	2 to 3 hours	Continuous
Slow Sand Filtration	1 to 2 hours	1 to 2 hours
Bag and Cartridge Filtration	1 to 2 hours	1 to 2 hours
Membrane Filtration	1 to 2 hours	N/A [3]

Notes:

1. Comprehensive automation should include continuous on-line finished water turbidity, chlorine residual measurements, and finished-water storage volumes. Automatic plant shut down capability for turbidity, chlorine residual, and finished water storage parameters connected to auto dialers or similar equipment to alert 24-hour on-call personnel of equipment failures. For conventional and direct filtration, flow-paced streaming current actuated coagulant feed control, automatic backwash, and automatic filter-to-waste capability before start-up and after backwash should be provided.
2. Facilities with limited automation are those that do not meet the recommendations for comprehensive automation as described in Note 1 above.
3. Not Applicable. Limited automation may not be justified for these technologies. In most cases, continuous operator presence is impractical for these technologies.

Reliability guidelines for surface water facilities include those in the "Policy Statement on Automated/Unattended Operation of Surface Water Treatment Plants" in the *Recommended Standards for Water Works* (Ten State Standards 2007). According to this policy statement, in their project reports, engineers should:

- Identify all critical features in the treatment facility that will be monitored electronically. Describe automatic plant shutdown controls with alarms and conditions that would trigger shutdowns. Dual or secondary alarms may be necessary for certain critical functions.
- Provide automated monitoring of all critical functions with major and minor alarm features. Automated plant shutdown for all major alarms. Inability to automatically startup the plants following a major alarm. Built-in control test capability to verify the status of all major and minor alarms.
- Discuss the ability to operate all treatment plant equipment and process functions manually through the control system.
- Outline plans to challenge test each critical component.

Engineers should consult several additional items in the policy during the pre-design process for a surface water treatment facility.

Nitrate: Engineers should design treatment processes for nitrate, and other acute chemical contaminants with the same degree of reliability as a surface water treatment plant. As noted in Section 2.9 of the *Recommended Standards for Water Works* (Ten State Standards 2007), ion exchange plants for nitrate removal should continuously monitor and record the treated water nitrate levels. This level of precaution is because treatment failure and subsequent exposure to the contaminant may cause an immediate threat to human health.

12.4.5 Chemical Overfeed

Injecting concentrated chemicals into the water supply always poses some threat of overfeed if equipment is not designed, installed, operated, or maintained properly. Overfeeds of ammonia, chlorine, sodium hydroxide, and fluoride have been reported in recent years (Brender et al. 1998; AWWA 1993; AWWA 2004; Lee et al. 2002; Liang et al. 2006).

Operator error, design flaws, mechanical failure, installation errors, or a combination of factors can cause these failures. Documented failures include:

- **Ammonia Overfeed.** An ammonia injection point was moved downstream in the process to increase free chlorine contact time prior to chloramine formation, and the hydraulic head on the bulk storage tank was sufficient to allow ammonia to flow into the main without pumping. The antisiphon valve designed to prevent an overfeed failed, allowing the full bulk storage tank to empty into the water system. Operators failed to recognize the problem despite unusually high pH values and unusually low chlorine residuals.

- **Sodium Hydroxide Overfeed.** To control corrosion, the water system treated a well supply with NaOH. When operators closed the distribution system valves to complete a main repair, the pressure at the well increased significantly, reducing well production from 450 gpm to less than 85 gpm. The caustic feed system was not flow paced. As a result, the pH of the water eventually reached 13. Two people who drank water from a nearby public fountain received mouth and throat burns. The pressure and pH build-up occurred over a two-day period; daily inspection of the well and treatment system would have caught the problem sooner.
- **Fluoride Overfeed.** In 1992, an incident in Hooper Bay, Alaska caused 1 death and about 262 illnesses. An incorrectly wired circuit for the fluoride feed pump (in parallel instead of in series) allowed fluoride solution to pump into the water system even though the source wasn't operating. This "slug" of fluoride (up to 150 mg/L) was delivered to customers.
- **Chlorine Overfeed.** A computer controller card on a rate-of-flow controller malfunctioned, failing to shut down the chlorination circuit when the well sources (controlled by reservoir levels) shut off. Nearby customers noticed the continued injection of chlorinated water when the well sources were called on again, and the water was delivered to the distribution system.

As these examples show, overfeeds occur for various reasons. Design, operation, and routine maintenance considerations can minimize the potential for overfeed.

1. Purveyors should consider day tanks when they use large bulk volumes of treatment chemicals. These tanks promote daily inspection of the feed systems, and would reduce the magnitude of an overfeed.
2. Proper design and installation of the chemical feed system components is critical. The design engineer should evaluate the failure modes of the equipment, and add redundancy if needed. In the chlorine and fluoride overfeed examples above, a redundant flow switch wired in series with the feed pumps would have stopped the chemical injection system after it detected a lack of treated water flow.
3. Engineers should select chemical injection points to minimize the potential for siphoning or hydraulically draining chemical storage tanks, even if their design includes antisiphon features.
4. Where possible, the design should include continuous monitoring equipment (pH, chlorine, fluoride) with integrated alarms. It is appropriate for these alarms to automatically shutdown the equipment.
5. Water systems should ensure operators receive the training they need to understand the equipment, its installation, and proper maintenance and monitoring responsibilities. Operator error, or operator inattention caused or aggravated several of the overfeed incidents described above. Operations and maintenance manuals should tell operators how to react to unexpected changes in water quality parameters (increasing or decreasing pH, values outside "normal" ranges, and other issues).

6. Routine equipment maintenance is essential. For example, water systems should periodically inspect their antisiphon valves and replace them as needed.

Other ways the design can minimize the risk of chemical overfeed are in Part 5 of the *Recommended Standards for Water Works* (Ten State Standards 2007).

12.5 Construction Documents

Before water systems install new or expanded treatment facilities DOH **must** approve their detailed construction documents (WAC 246-290-120). The construction document submittal **must** include detailed construction drawings and specifications. Some small projects may include relevant specifications on the construction drawings if applicable. Chapter 3 summarizes the information that must be in all construction document submittals. Design engineers should review the checklists in Appendix A to confirm they meet the minimum submittal requirements.

12.6 Construction Inspection and Final Approval

A licensed engineer **must** complete a *Construction Completion Report Form* (DOH 331-121) and submit it to DOH before water systems can use treatment facilities to serve water to the public (WAC 246-290-120(5)). On the *Construction Completion Report Form* (DOH 331-121), the design engineer **must** confirm that disinfection procedures, pressure or leakage testing, and bacteriological tests comply with regulatory requirements and project specifications. Chapter 14 includes more information on construction inspection and final approval.

Most water treatment facilities **must** complete additional start-up and testing requirements prior to certification of construction completion (WAC 246-290-120(4)). See Section 12.4.3 for more information on start-up and testing for water treatment facilities.

12.7 Related Policies and Guidelines

The appendices do not address all possible treatment alternatives. Therefore, the design engineer should contact DOH (see Appendix A) to determine if a current policy or guideline is available for the specific treatment alternative under consideration.

12.8 Treatment Alternatives

The tables in this chapter list acceptable treatment technologies for different treatment classifications and water quality parameters. These technologies are acceptable due to specific federal or state regulatory language and demonstrated past performance. Specific design standards and specifications for technologies in the tables came from a variety of textbooks, guidelines, policies, and industry publications.

The acceptable treatment technologies in Tables 12-3 through 12-8 are established technologies. The "alternative technologies" in Tables 12-3 and 12-6 are new or innovative facilities or treatment techniques. Alternative technologies for surface water treatment **must** undergo a stand-alone approval process prior to installation in any specific site (WAC 246-290-676(2)(b)).

Depending on the technology, DOH may require laboratory and pilot studies before the engineer develops specific designs (WAC 246-290-250). Check with the DOH regional office (see Chapter 1) before proceeding with an alternative technology.

Manufacturers may develop testing protocols that demonstrate adequate treatment performance by using the EPA/NSF Environmental Testing Verification (ETV) program. Information on these protocols is on the NSF Web site at http://www.nsf.org/. Technologies not specifically on the tables may apply, but will require some level of special study and field-testing to demonstrate effectiveness and reliability.

Water systems may seek a variance when the characteristics of reasonably available source water make it impossible to meet an MCL. DOH will not consider variances for compliance with coliform MCL violations or surface water treatment requirements (WAC 246-290-060(2)). To date, DOH has not granted any water system a variance from a primary MCL violation.

The tables in this section list applicable treatment technologies for surface water treatment, disinfection, corrosion control, inorganic chemicals (IOCs), volatile organic chemicals (VOCs), synthetic organic chemicals (SOCs), and disinfection byproducts (DBPs). Treatment technologies for fluoridation, radionuclides, and aesthetic concerns are also described briefly.

12.8.1 Surface Water

Engineers may use various treatment alternatives to comply with surface water filtration requirements including:

- Conventional filtration
- Direct filtration
- Diatomaceous earth filtration
- Slow sand filtration
- Membrane filtration
- Bag and cartridge filtration

Engineers should consider the raw water quality and water system size when selecting the most appropriate filtration technology for a water system. Table 12-3 includes basic information on these filtration processes. Additional design, operating, and performance criteria for surface water treatment are in chapter 246-290 WAC, Part 6 and *Surface Water Treatment Rule Guidance Manual* (DOH 331-085). EPA also published a list of treatment technologies applicable to small water systems (USEPA 1998a).

Many surface water treatment facilities have alarms and comprehensive automation that allow the facility to operate without staff present. Reliability requirements and design issues related to automation are in Section 12.4.4.

Table 12-3: Surface Water Treatment

Established Technologies	Turbidity Range (NTU) [1]	Color Range (CU) [1]	Maximum Filtration Rate (gpm/ft^2) [2]	General Design References
Conventional Filtration	Unlimited	< 75	6.0	Kawamura 2000b
Direct Filtration	< 15	< 40	6.0	Kawamura 2000b
Pressure Filtration	< 5	< 10	3.0	Ten State Standards 2007 [3]
Diatomaceous Earth Filtration	< 10	< 5	1.0	AWWA 1999; Fulton 2000; WSDOH 2003b
Slow Sand Filtration	< 10	< 10	0.1	Hendricks et al. 1991, WSDOH 2003b
Alternative Technologies				
Bag and Cartridge Filtration	< 5	See Note 4	See Note 4	USEPA 2003a
Membrane Filtration	See Note 4	See Note 4	See Note 4	USEPA 2005

Notes:

1. Water quality limitations are adopted from the DOH Surface Water Treatment Rule Guidance Manual (DOH 331-085) and references cited therein.
2. Maximum filtration rates are lower for conventional, direct, and pressure filtration if single media filter beds are used, instead of deep bed, dual or mixed media filters (see WAC 246-290-654).
3. According to Section 4.2.2 *Recommended Standards for Water Works* (Ten State Standards 2007), pressure filters are for iron and manganese removal, and **must not** be used for filtration of surface water.
4. Special studies are required to determine limitations, which are equipment specific.
5. Multiple filter units required in WAC 246-290-678(2)(c).
6. Filter to waste capability **must** be provided for all surface water treatment facilities (WAC 246-290-676(4)(b)(iii)).

12.8.2 Disinfection

Disinfection treatment approaches differ depending on the intended purpose of the application. Water systems **must** treat surface water or GWI to inactivate protozoa and viruses (WAC 246-290-601(1)). When needed, groundwater disinfection targets bacterial and viral pathogens. If a groundwater source is contaminated—or vulnerable to microbiological contamination—disinfection **must** meet minimum disinfection requirements at the entry point to the distribution system (WAC 246-290-451(3)). Water systems may also disinfect to maintain a distribution system residual and comply with the total coliform rule.

For surface water and GWI sources, disinfection combined with filtration **must** provide at least 3-log (99.9 percent) removal or inactivation of *Giardia lamblia*, and at least 4-log (99.99 percent) removal or inactivation of viruses (WAC 246-290-662(1)). Filtration credit for removal of *Giardia lamblia* cysts and viruses establishes the minimum disinfection inactivation requirement. Irrespective of filtration credit, water systems **must** provide at least 0.5-log inactivation of *Giardia lamblia* cysts (WAC 246-290-662(1)(c)).

Water systems that meet the criteria to remain unfiltered **must** provide disinfection sufficient to meet at least (WAC 246-290-692):

- 2-log inactivation of *Cryptosporidium* oocysts.
- 3-log inactivation of *Giardia lamblia*.
- 4-log inactivation of viruses.

Primary groundwater disinfection **must** provide a CT of at least 6, which is roughly equal to disinfection that provides 4-log inactivation of viruses (WAC 246-290-451(3)). It is unusual to find protozoa in protected groundwater, so DOH doesn't require disinfection for *Giardia lamblia*.

DOH expects unfiltered water systems using the limited alternative to filtration option to provide primary treatment (disinfection) capable of achieving greater than 2-log (99 percent) inactivation of *Cryptosporidium* oocysts. Water systems considering this option should consult chapter 246-290 WAC, Part 6 for specific requirements, and contact the DOH regional engineer (see Table 1-1).

Table 12-4 is a list of applicable disinfection technologies for groundwater and surface water. The table cites specific recommendations for "typical applications," and notes specific issues associated with each technology. Additional performance criteria for groundwater and surface water disinfection are in chapter 246-290 WAC, Parts 5 and 6.

Primary disinfection for seawater sources treated with reverse osmosis should achieve at least 4-log inactivation of viruses. Although reverse osmosis effectively removes viruses, the primary disinfection provides a multiple barrier in case the integrity of the membranes or another water system component is compromised. *Giardia lamblia* cysts do not survive well in saltwater, so DOH does not require seawater sources to meet the disinfection and filtration requirements of the Surface Water Treatment Rule.

Purveyors should base primary disinfection for a salty well treated with reverse osmosis on the:

- Construction of the well.
- Degree of wellhead protection.
- Aquifer characteristics.
- Bacteriological history of the source.

12.8.3 Fluoridation

Technologies acceptable for fluoridating drinking water include liquid and dry feed systems. DOH does not require pilot studies for new or expanded fluoridation treatment facilities. Engineers should size and design fluoride feed equipment to prevent overfeed while providing the required target dose. Engineers can usually verify their fluoride feed-rate design assumptions during the start-up, testing, and operation period.

Table 12-4: Disinfection Treatment

Established Technologies	Typical Application	Notes
Chlorine Gas	Primary/ Secondary	Consumes alkalinity and may reduce pH. Requires a risk management plan if >2,500 lbs. stored on site (see 40 CFR 68). Use of gaseous chlorine may trigger an International Fire Code requirement for spill mitigation measures such as containment or scrubbers. Proponents of new installation should coordinate this with the local fire prevention authority. Must evaluate total trihalomethane (TTHM) and haloacetic acids five (HAA5) formation.
Hypochlorination	Primary/ Secondary	Design must evaluate expected storage time and affect on solution strength, potential for strength dilution to minimize these problems; must evaluate TTHM and HAA5 formation.
Chlorine Dioxide	Primary/ Secondary	On site generation. Maximum allowable ClO_2 concentration at entry = 0.8 mg/L (as ClO_2), MCL for chlorite = 1.0 mg/L Use triggers additional monitoring for chlorine dioxide and chlorite.
Ozone	Primary	Pilot work required to determine decay and demand characteristics. May significantly increase biodegradable organic matter in treated water, which may require secondary disinfection. MCL for bromate = 0.010 mg/L.
Chloramines	Secondary	Background ammonia levels must be considered, requires close operator attention to ensure proper ammonia-chlorine ratio. Design must provide overfeed protection. Water systems proposing changeover from free chlorine should evaluate the potential for elastomer degradation (Reiber 1993).
Irradiation (UV light) See Appendix I	Primary	Minimum applied UV dose for groundwater applications is 186 mJ/cm^2 for 4-log virus inactivation. Reactor validation uncertainties will require the applied reduction equivalent dose (RED) to be even greater than this threshold. If UV is the primary surface water disinfectant, a RED of at least 40 mJ/cm^2 is required. Additional information and guidance is available from EPA (USEPA 2006a) and DOH.
On-Site Hypochlorite Generation	Primary/ Secondary	See notes for hypochlorination above. ANSI/NSF Standard 60 certified sodium chloride (salt) must be used to generate the hypochlorite solution. The design should address ventilation for hydrogen gas to minimize the risk of explosions.
Tablet Chlorinators	Primary/ Secondary	See notes for hypochlorination above. Design should consider potential for variations in chlorine dosage.

Notes:

1. Primary disinfection used to inactivate pathogenic organisms from source water.
2. Secondary disinfection used to maintain a distribution system residual.
3. Disinfection performance requirements are detailed in chapter 246-290 WAC, Parts 5 and 6.
4. Disinfection system automation should include flow-paced (proportional) chemical feed; automatic system shutdown upon low/high residual or equipment failure; or automatic dialer to on-call personnel upon residual or equipment failure.

In their designs, engineers should evaluate how the selected fluoridation process will affect source water pH and compliance with the Lead and Copper Rule. This manual doesn't contain specific recommendations for fluoridation technologies, which are available in references such as *Water Fluoridation: A Manual for Engineers and Technicians* (Reeves 1986) and *Water Fluoridation Principles and Practices* (AWWA 2004). Appendix G includes a checklist for the design of sodium fluoride saturators. Water systems use saturators to add fluoride to sources, especially those with a capacity of less than 500 gpm.

Water systems using fluoridation **must** maintain a fluoride concentration between 0.8 mg/L and 1.3 mg/L at all points in the distribution system (WAC 246-290-460). This requirement ensures fluoridation is tightly controlled, effective, and reliable. Engineers should review this and other performance requirements during the design process.

12.8.4 Corrosion Control

Table 12-5 cites acceptable corrosion control technologies and identifies issues associated with them. Water systems exceeding the lead or copper action levels **must** conduct corrosion control studies and implement optimal corrosion control treatment (chapter 246-290 WAC and 40 CFR 141.80 through 141.90 (Subpart I)). Engineers can use a series of flow charts in the *Revised Guidance Manual for Selecting Lead and Copper Control Strategies* (Spencer 2003) to identify appropriate technologies for water systems that exceed the lead or copper action levels. This document is on EPA's Web site (see Appendix C). Water systems that exceed an action level should contact their DOH regional office (see Table 1-1).

Although not required, DOH encourages water systems to use pipe-loop or other pilot scale work to evaluate actual corrosion or corrosion rates using a proposed treatment approach. DOH strongly recommends that purveyors and their engineers conduct bench scale work to verify that a proposed design dose-rate will meet treatment objectives (target pH or alkalinity). Purveyors **must** pilot test a physical stripping process to evaluate any seasonal variation in raw water quality and temperature that could affect the proposed treatment system (WAC 246-290-250).

12.8.5 Inorganic Chemicals

There are primary (health-based) or secondary (aesthetic) water quality standards for more than a dozen inorganic chemicals (IOCs) (chapter 246-290 WAC). However, few of these contaminants occur in Washington State at concentrations greater than the MCL.

The IOCs most frequently detected above their MCLs are arsenic (As), fluoride (F), nitrate (NO_3), iron (Fe), and manganese (Mn). Table 12-6 summarizes treatment options for these contaminants.

Chloride and conductivity are secondary contaminants that may indicate salt-water intrusion. DOH and local health departments may require additional action when salt-water intrusion threatens the reliability of the water supply. See Section 7.1.2 for more information on salt-water intrusion.

Table 12-5: Corrosion Control Treatment

Established Technologies	Notes
pH/alkalinity adjustment	
--Chemical Addition	Caustic soda (NaOH), lime ($Ca(OH)_2$), soda ash (Na_2CO_3), sodium bicarbonate ($NaHCO_3$), calcium carbonate ($CaCO_3$), potassium hydroxide (KOH) and carbon dioxide (CO_2) (USEPA, 1992; Economic and Engineering Services, 1990).
--Calcite Contactor	Applies to small water systems (generally less than 500 people). No danger of chemical over-feed and is usually not operator intensive. Generally applies when Ca^{2+} < 30 mg/L, alkalinity < 60 mg/L (both as $CaCO_3$) and pH low (<7.2). Potential clogging due to Fe/Mn and other particulate matter. Waters with significant natural organic matter (>2 mg/L total organic carbon (TOC)) should be evaluated to ensure that organic deposits will not interfere with the dissolution of media over time.
--Aeration/Air Stripping	Suitable for groundwater high in CO_2 , effectiveness controlled by alkalinity and aeration system design, capital costs usually high, pre- or post-aeration disinfection should be provided. Pilot work to verify design parameters (for example, height, packing, air and water ratio) must be completed.
Calcium Carbonate Precipitation	Calcium carbonate precipitation is not a viable approach for corrosion control in the Pacific Northwest due to the region's relatively soft waters.
Inhibitors	
--Ortho - / Poly - / Blended Phosphates	Phosphate based inhibitors are pH sensitive, so the pH range should be maintained with the range of 7.2 to 7.8. Disinfection is required along with the addition of phosphates.
--Silicates	Sodium silicate inhibitors are not well understood (USEPA 1992; Reiber 1990). Silicate effectiveness thought to be a combination of concurrent pH increase and protective film on piping walls.

Notes

1. Protection from treatment chemical overfeed must be provided. This includes appropriate hydraulic design and antisiphon protection. The use of day tanks is strongly recommended.
2. Lime and soda ash feed systems may be operator intensive because of plugging potential in feed equipment and piping.
3. DOH recommends that bench or pilot scale testing for selected technologies (aeration, calcite contactors, and pH adjustment) accompany use of analogous system justification. These may be oriented toward ensuring that target pH/alkalinity goals are met rather than measuring resulting corrosion rates. In some cases, water systems have had difficulty matching full-scale results to bench scale data, and extreme care must be applied in sample handling. Chemical metering pumps should be sized with flexibility to account for potential differences, and bench scale results should be compared to theoretical expectations based on water chemistry.

Table 12-6: Treatment Technologies for Selected IOCs

Established Technologies	Contaminant	Notes	References
Oxidation/Filtration	As, Fe, Mn	Oxidation kinetics pH sensitive (principally Mn), organic matter will increase oxidant demand. Fe addition may be required to remove As. Filtration rates dependent upon technology and water quality.	Hoffman et al. 2006; HDR 2001
Cation Exchange	Fe, Mn	Should not be used if the concentration of Fe and Mn is greater than 0.3 mg/L. Must prevent oxidation prior to ion exchange or resin will foul. Waste disposal of brine may be an issue.	Ten State Standards 2007
Anion Exchange	As, NO_3	Use nitrate selective resin (for NO_3), As: Oxidize As(III) to As(V), Competition with sulfate and other ions must be evaluated. Total dissolved solids should be <500 mg/L. Post-column pH adjustment required. Evaluate waste disposal issues.	Clifford 1999; USEPA 2003; WSDOH 2005
Activated Alumina	F	pH adjustment required to maximize adsorption, pH adjustment not recommended for small water systems due to operational complexity and safety issues.	Clifford 1999
Iron Based and Other Specialized Adsorbents	As	Performance of adsorbents varies with vendor and water quality. Some adsorbents do not remove As(III). If As(III) is present, pre-oxidation may be required.	USEPA 2003b; WSDOH 2003a
Reverse Osmosis (RO)	As, F, Fe, Mn, NO_3	Post treatment corrosion control may be required, high operation cost, sizing strongly temperature sensitive, concentrate disposal issues must be evaluated. As (III) should be oxidized to As (V). Side stream blending may be appropriate.	USEPA 2005; USEPA 2003b
Sequestration	Fe, Mn	For source water with a combined *Fe/Mn* concentration of less than 1.0 mg/l (*Mn* < 0.1 mg/l). May be applicable at higher concentrations, however, these applications should conduct bench scale studies and will be allowed only on existing sources. Disinfection required.	Robinson et al. 1990; HDR 2001; Ten State Standards 2007.
Alternative Technologies	**Contaminant**	**Notes**	**References**
Biological Removal	NO_3, Fe, Mn	Not in widespread use in United States. Substantial pilot work (1 year continuous operation at a minimum) would be required to establish biological process, and post-treatment disinfection must be provided. Taste and odor control issues.	HDR 2001; WSDOH 2005

Notes:

1. Pilot testing is expected for all technologies listed above. See Section 12-3 for additional pilot testing information.
2. The listed technologies may be capable of removing other inorganic chemicals. Contaminants are listed in this column if typical removal rates for the specific technology are expected to be greater than 70 percent in most applications as indicated in selected references.
3. Conventional filtration and lime softening can remove the selected contaminants, but new installations are generally not cost effective for IOC removal alone.
4. Manufactured media and equipment must meet the requirements of WAC 246-290-220.
5. Processes listed above are expected to require a minimum of 6-8 hours per week of operator involvement, although some may require more. Water systems proposing to install a treatment system should contact existing facilities and participate fully in pilot work to better assess long-term operator needs.
6. Instrumentation/control that may be appropriate includes: Automatic plant shut down for process equipment and pump failure, auto-dialers or similar equipment to alert 24-hour on-call personnel of plant failures, on-line filtered or finished water monitoring equipment and automatic filter-to-waste capability.

12.8.5.1 Arsenic

The arsenic MCL is 10 parts per billion (0.010 mg/L). Water systems that exceed the arsenic MCL should consider both treatment and non-treatment alternatives. Guidance documents and research reports can help water systems evaluate options for complying with the arsenic MCL. For example, *Arsenic Treatment for Small Water Systems* (DOH 331-210) discusses arsenic occurrence in Washington State and compliance alternatives. The EPA and Water Research Foundation (formerly AwwaRF) also produced guidance documents and research reports. There are many guidance documents on EPA's Web site (USEPA 2003b; Hoffman 2006).

12.8.5.2 Nitrate and Nitrite

Nitrate and nitrite are acute contaminants for susceptible individuals (primarily infants less than 6 months old and pregnant women). That means a single exposure can affect a person's health. Nitrate and nitrite contamination usually occurs in groundwater supplies in agricultural areas. Information on nitrate occurrence in Washington State and a discussion of treatment and non-treatment alternatives for nitrate is in the DOH guidance document *Nitrate Treatment Alternatives for Small Water Systems* (DOH 331-309). See the references cited in the guidance document for information on nitrate treatment.

12.8.5.3 Iron and Manganese

Iron and manganese frequently occur in groundwater at concentrations above their secondary MCLs. Purveyors usually use oxidation combined with filtration to remove iron and manganese from drinking water. Common oxidants are air, chlorine, potassium permanganate ($KMnO_4$), and ozone. The design engineer should be aware of water quality issues such as total organic carbon, pH, and competing ions that can adversely affect treatment performance. The limitations of treatment options for iron and manganese are in Table 12-6 and other texts (HDR 2001; Sommerfeld 1998; Faust and Aly 1998). Additional requirements for iron and manganese treatment are in Appendix B and Appendix G.

12.8.6 Volatile Organic Chemicals and Synthetic Organic Chemicals

A list of treatment technologies acceptable for removing volatile organic chemicals (VOCs) and synthetic organic chemicals (SOCs) is in Table 12-7. In addition to specific technologies, this table identifies selected issues the engineer should consider. In most cases, due to the complexity of treatment processes for specific organic contaminants, the engineer will have to use pre-design studies and pilot tests to determine whether the processes apply to specific situations.

12.8.7 Disinfection Byproducts

Disinfection byproducts (DBPs) can form whenever a chemical disinfectant is added to drinking water. Therefore, all community and nontransient noncommunity water systems that distribute water to which a disinfectant has been added **must** monitor for DBPs (WAC 246-290-300(6)). All affected water systems **must** monitor for total trihalomethanes (TTHMs) and the five currently regulated haloacetic acids (HAA5). In addition, water systems that use chlorine dioxide

must monitor for chlorite and most that use ozone **must** monitor for bromate (WAC 246-290-300(6)(b)).

Water systems usually control DBPs by minimizing the contact between chemical disinfectants and DBP precursors such as natural organic matter. Table 12-8 lists technologies purveyors should consider to reduce the formation of DBPs or remove DBP precursors. EPA has a number of manuals on this subject (USEPA 1999a; USEPA 1999b; USEPA 2001).

12.8.8 Radionuclides

There are MCLs for radium-226, radium 228, gross alpha particle radioactivity, beta particles, photon emitters, and uranium (30 ug/L). This manual does not include a detailed discussion on radionuclide treatment because radionuclide contamination above current MCLs is rare in Washington State.

Purveyors **must** use pre-design studies and pilot tests to determine treatment and waste disposal options appropriate for their specific situations. Water systems can remove radium and uranium from drinking water by using properly designed ion exchange treatment processes (Clifford 1999). Reviews of other treatment processes and the waste disposal issues related to them are available elsewhere (USEPA 2006b).

12.8.9 Taste, Odor, and Color

Many treatment technologies also remove taste, odor, or color, with varying degrees of success. However, due to the variety and complexity of treatment technologies for taste, odor, and color in specific circumstances, DOH recommends field studies before engineers implement final designs. DOH regional engineering staff can help engineers develop protocols for implementing design studies.

Table 12-7: Treatment Technologies for VOCs and SOCs

Technologies	Notes
Granular Activated Carbon (GAC)	A best available technology for removal of VOCs and SOCs. May require pre-filtration to remove particulate matter. Competition for GAC sorption sites with natural organic matter may occur. Seasonal increases in competing species may cause desorption of contaminant and must be fully evaluated. Requires reactivation of carbon on a regular basis (site and contaminant specific).
Powdered Activated Carbon (PAC)	May be effective for VOC and SOC removal, adequate mixing and contact time must be provided, existing settling and filtration must effectively remove added PAC. May be used seasonally if problem is not continuous. EPA considers PAC an “emerging” technology for VOC removal (USEPA 1998b).
Aeration	A best available technology for removal of VOCs and some of the more volatile SOCs. Established technologies include packed tower, diffused, and multiple tray aeration. Some alternative configurations require evaluation through pilot studies (see WAC 246-290-250). Design goals and operational parameters control performance. Aerated water should be disinfected to prevent significant growth of heterotrophic plate count bacteria (Umphres et al. 1989).
Chlorine/Ozone oxidation	Applies to glyphosphate only. See Disinfection Section for specific issues related to these technologies.

Notes:

1. Pilot testing is required for all technologies listed above, and may be required over periods of varying water temperature, and varying contaminant concentrations, if applicable. See Section 12-3 below for additional pilot testing information.
2. Manufactured media and equipment must meet the requirements of WAC 246-290-220.

Table 12-8: Treatment Technologies for Reduction of DBPs

Precursor Removal	**Notes**
Enhanced Coagulation	Suitable only for conventional surface water plants. Nature of source water organic material, treatment conditions (coagulation pH) and background alkalinity control effectiveness. Requires significant coagulant doses. Required Treatment Technique according to the Stage 1 D/DBP Rule for surface water treatment plants that use conventional rapid rate filtration.
Granular Activated Carbon	GAC10 (empty bed contact time of 10 minutes) and reactivation period of carbon of no more than every six months. This is a best available technology for removal of DBP precursors, although performance is dependent on the selected GAC and the nature of the organic matter to be removed.
Powdered Activated Carbon (PAC)	Suitable only for conventional surface water plants or potentially membrane applications. Effectiveness dependent on the nature of the organic matter present, the must be demonstrated through long-term pilot (at least 1 year of operation).
Biologically Active Filtration	Use of preozonation followed by a rapid rate filtration process. Filter media may be GAC, anthracite, sand, or some combination. TOC removals in the 20-70 percent range possible, dependent on the nature of the organics present, ozone: TOC dose, and filter contact time (Carlson and Amy 1998).
Slow Sand Filtration	Standard slow sand filtration expected to remove 5-25 percent of raw water organic matter (as TOC) Use of preozonation will increase removal, however long term piloting (at least 1 year of operation) is required to determine effectiveness and affect on filter cleaning requirements (Eighmy et al. 1993).
Membranes	Nanofiltration can effectively remove DBP precursors. Unamended ultra- or microfiltration will not generally remove precursors. Use of PAC in ultrafiltration water systems has been effectively demonstrated (AwwaRF et al. 1996).
DBP Removal or Mitigation	
Aeration	Some volatile DBP (such as chloroform) can be significantly removed through appropriately designed aeration processes (Billeo et al. 1986; Wolfoort et al. 2008). Temperature and air-water ratio are significant design factors.
Alternative Disinfection/Application	Use of chloramines in distribution systems with long detention times or ozone or chlorine dioxide as a primary disinfectant may mitigate the formation of regulated DBP sufficiently. See Table 12-4 for issues specific to these approaches.

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12.9 Cross-Connection Control Considerations in Water Treatment Facilities

Protecting drinking water from contamination starts at the source and continues through treatment facilities designed to improve water quality. In water treatment facilities, this protection requires engineers to incorporate safeguards into the designs for their treatment processes and basins.

12.9.1 Treatment Chemicals

In water treatment facilities, the improper storage and application of treatment chemicals may present a type and level of potential hazard similar to that at an industrial or chemical plant. Treatment plants and some distribution treatment facilities store large quantities of materials that are indistinguishable from their industrial counterparts. These materials include chlorine, hypochlorite compounds, aluminum sulfate, caustic soda, potassium permanganate, and numerous proprietary organic polymers. Typical treatment practices feed these products directly into treated potable water or water being processed into potable water. Most treatment works also contain significant quantities of nonpotable raw, or incompletely treated water.

DOH does not consider the intentional, controlled addition of an approved treatment chemical (certified under ANSI/NSF Standard 60) at the appropriate location and dosage a "cross-connection." The controlled application of treatment chemicals is precisely what makes many waters potable. However, even the intentional addition of chemicals could result in a dangerous overfeed due to improper selection, installation, operation, or maintenance of feed equipment, or due to component failure. Design manuals such as the *Recommended Standards for Water Works* (Ten State Standards 2007) or *Water Fluoridation Principles and Practices* (AWWA 2004) provide information and recommendations for controlling and preventing these types of failures.

12.9.2 Premises Isolation

Potable water in a treatment facility is often at atmospheric pressure. Reduced pressure in the potable water increases the potential for cross contamination, particularly that due to backflow or backsiphonage. This may involve treatment chemicals, or raw or partially treated water.

Tables 4-2 and 4-4 of the *Cross Connection Control: Accepted Procedures and Practice Manual* (PNWS-AWWA 1996) recommend premises isolation for industrial facilities with chemical feed tanks. Premises isolation protects the water supply by installing backflow prevention assemblies at or near the point where water enters a premises. Because the chemical hazards in a waterworks facility can be identical to those in industrial facilities, DOH requires water facilities to have the equivalent of premises isolation.

12.9.3 Process Water and In Plant Piping

A treatment facility may use in-house process water to dilute chemicals, carry concentrated feed solutions, drive eductors, provide mixing, operate surface washers, or other purposes. Table 12-9 recommends backflow prevention assemblies for equipment and processes common at water treatment plants. The complexity of the piping system in many water facilities increases the probability that an existing cross connection will go undetected—or that a new cross connection might be inadvertently established. Therefore, treatment facilities should take potable water for use in the facility from no more than one or two discrete points. They should install backflow prevention assemblies at or near each of these points. Furthermore, to facilitate identification of piping, DOH recommends that facilities use a piping color code such as that in *Recommended Standards for Water Works* (Ten State Standards 2007).

Because premises isolation does not protect personnel or ensure the integrity of process components within a treatment facility, the treatment facility should provide an entirely separate “potable” house supply or “fixture” protection. See Table 4-4 of *Cross Connection Control: Accepted Procedures and Practice Manual* (PNWS-AWWA 1996).

12.9.4 Common Wall Construction in Treatment Facilities

Although more of a design and construction element, engineers should consider ways to prevent cross connection contamination that could occur if the common walls between water being treated (nonpotable) and finished water (filtered) fail. Although this is a greater concern for package-filtration treatment plants, it could apply to any treatment process designed with adjacent walls between various unit processes. DOH expects engineers to design and construct double-wall separation (providing an air space) between unfiltered water, such as flocculation and sedimentation basins, and filtered water (underdrains and clearwell for filtered water) so operators can check for fractures in either wall’s integrity (the air space will fill with water).

Table 12-9: Recommended Protection at Fixtures and Equipment Found in Waterworks *

AG	Air Gap	PVBA	Pressure Vacuum Breaker Assembly
AVB	Atmospheric Vacuum Breaker	RPBA	Reduced Pressure Backflow Assembly
DCVA	Double Check Valve Assembly		

Description of Fixture, Equipment, or Use	Minimum Protection at Fixture
Raw and process water tanks	Provide AG on overflow and drain
Bulk liquid chemical storage tanks	1. Provide AG on dilution water supply line, and 2. AG on overflow and drain, and 3. Provide day tank
Day tanks	1. Provide AG on dilution water supply line, and 2. AG on overflow and drain, and 3. Size to hold no more than a 30-hour supply
Dry chemical feeder solution tanks	1. Provide AG on fill supply line, and 2. AG on overflow and drain
Saturators	1. Provide AG or AVB on fill supply line, and 2. AG on overflow and drain
Chemical feed pumps, general	1. Assure discharge at point of positive pressure, or 2. Provide vacuum relief (antisiphon device), or 3. Provide other suitable means or combinations as necessary to control siphoning 4. No pump priming or flushing line
Chemical feed pumps, fluoride compounds	In addition to general recommendations for chemical feed pumps, these precautions apply: 1. Provide dedicated electrical connection interlocked with well or service pump, and 2. Provide two diaphragm-type antisiphon devices (one at pump head, one at injection point), and 3. Size pumps to operate at 30 percent-70 percent of capacity.
Chemical carrying line, chemical injection line, eductor line	Provide RPBA
Chemical injection line in common between potable water and nonpotable water	Provide RPBA or manifold chlorine gas rather than chlorine solution, eliminating cross-connection (use separate injectors for raw and filtered water, if applicable)
Surface washers	Provide AVB or PVBA or DCVA
Filter backwash waste discharge	Provide AG to waste
Filter-to-waste	Provide AG to waste, or AG to process stream ahead of filters
Membrane clean-in-place systems	Provide physical disconnect
Sample lines to monitoring equipment	Provide AG or AVB
Monitoring equipment for raw and potable water that is used in common	Provide AG or physical disconnect
Hose bibb connections	Provide hose bibb vacuum breaker (above hose outlet)

*These recommendations assume premises or area isolation. Air gaps to treated or partially treated water must be screened.

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Chapter 13: Miscellaneous Design Considerations

This chapter describes the safety concerns purveyors should consider when designing water facility projects. The chapter includes cross-connection control and seismic risk information the design engineer must evaluate where required.

13.1 Safety

Improperly designed facilities could put employees, contractors, and the public at risk. If someone gets hurt, the water system may face a lawsuit or citations and penalties from the Washington State Department of Labor and Industries (L&I). Purveyors, contractors, and employees should always take precautions to ensure a safe working environment as required by state and federal law (Washington Industrial Safety and Health Act, 49.17 RCW; Occupational Safety and Health Act).

This section on safety briefly summarizes issues engineers and purveyors must consider in the design of water systems. More detailed safety information can be obtained by contacting L&I or accessing the L&I Web site at www.lni.wa.gov/safety/default.asp

Safety topics on the L&I Web site include:

- Asbestos
- Confined spaces
- Excavation and trenching
- Fall protection
- Guardrails
- Ladders
- Lead
- Lockout/Tagout

Contact information for L&I and Occupational Safety and Health Administration (OSHA) is in Appendix C.

13.1.1 Confined Spaces

Given the danger and maintenance difficulties associated with confined spaces, a water system design should minimize the number of confined spaces. However, it is often impractical to avoid confined spaces altogether. Most storage tanks and underground vaults are confined spaces.

The definition of a confined space has three features:

1. Large enough for a person to enter.
2. Restricted entry or exit.
3. Not designed for continuous occupancy.

Two hazards associated with confined spaces are: 1) poor air quality, and 2) the danger of engulfment. Designs for storage tanks and underground vaults should facilitate the circulation of fresh air into confined spaces when workers are present. The vent design should make it possible to easily clear debris from the vents. Purveyors should identify and eliminate any design feature that could allow inadvertent tank flooding. Confined space requirements are in chapter 296-809 WAC.

Lock-out and Tag-out

Purveyors must properly identify hazards with stored energy, such as water pressure from piping to the tank. To prevent someone from opening a valve at the wrong time, workers should use blind-flanges or a lock-out and tag-out system.

Access Hatches

Confined spaces are commonly designed with access hatches. These access hatches must have adequate clearances and address other L&I safety requirements. In addition, access hatches **must** have locks to prevent unauthorized entry and to help maintain the quality of the water (WAC 246-290-235(1)(a)). To facilitate air circulation and access for routine maintenance or emergencies, DOH recommends entries at the top **and** bottom of storage tanks, if possible. See Chapter 9 and WAC 246-290-235 for additional distribution-reservoir design requirements.

13.1.2 Ladder Safety and Fall Protection

Guardrails, ladders, and fall protection devices **must** meet the following L&I rules:

- Chapter 296-24 WAC, Part J-1: Working Surfaces, Guarding Floors and Wall Openings
- Chapter 296-155 WAC, Part C-1: Fall Restraint and Fall Arrest
- Chapter 296-155 WAC, Part K: Floor Openings, Wall Openings, and Stairways
- Chapter 296-876 WAC: Ladders, Portable and Fixed

Among other safeguards, L&I requires water system designs to:

- Protect openings and holes more than 12-inches across with either a cover that will support at least 200 pounds or a guard railing.
- Protect platforms and floor openings with properly designed guardrails and toeboards.
- Design fixed ladders with adequate clearances and provide side rails that extend at least 42-inches above the landing platform.

13.1.3 Antenna Location

A utility can get additional revenue by leasing space on storage tanks for antennas. However, improperly mounted equipment is a potential hazard to utility employees and could damage the tank coating system and structure. Antenna installations **must** meet all applicable electrical and safety codes. The antenna mounting should not cause a hazard to employees performing maintenance. Purveyors should not mount antenna cables on the climbing ladder or handrails.

13.1.4 Power Lines

According to *National Electric Code* guidelines, power lines should be at least 40 feet from work areas. If work must be performed within 10 feet of power lines, the electric utility should insulate the lines against contact. Only qualified persons with proper gear and equipment may work within 10 feet of power lines (WAC 296-24-960). High voltage power lines (50 kilovolts and greater) require larger separation distances. Under some circumstances, electricity can arc to equipment that is close to a power line, even if it is not touching the line. When engineers design tank sites, they should consider locating power lines underground. Contact L&I for specific requirements (see Appendix C).

13.1.5 Excavation and Trench Safety Systems

Excavation and trench safety systems **must** be based on local site and soil conditions (chapter 296-155 WAC, Part N). Contact L&I for specific requirements (see Appendix C). General L&I requirements include:

- Locating underground utilities prior to the start of excavation.
- A safe means of egress.
- Barriers to prevent people from falling into trenches.
- Safe storage of excavated materials.
- Properly designed shoring or other excavation support systems.

13.1.6 Dangerous Waste and Hazardous Materials

Check local and state rules on the proper handling and disposal of hazardous waste materials. In Washington, the Department of Ecology regulates handling and disposal of dangerous waste and hazardous materials.

Heavy Metals
Before purveyors remove previous tank paint coatings, they should test the paint for cadmium, chromium and lead. The concentrations of these heavy metals determine whether the Department of Ecology classifies dust from the removal project as dangerous or non-dangerous waste. When removing tank coatings, the tank owner could be considered a waste generator (chapter 173-303 WAC). In that situation, the utility is responsible for safely handling the generation and disposal of any waste product associated with the project. Contact Department of Ecology for further clarification (see Appendix C).

In addition, utilities and contractors **must** make sure construction workers take precautions to avoid inhaling heavy metals during removal of tank paint coatings, especially lead (WAC 296-155-176). Contact L&I for occupational health or construction safety information when dealing with any type of hazardous materials (see Appendix C).

Asbestos-cement
L&I **requires** special handling procedures when purveyors repair or replace asbestos-cement pipes. The utility and design engineer should contact L&I before working on or specifying asbestos-cement pipe. Chapter 296-62 WAC, Part I-1, addresses occupational exposure to asbestos. Chapter 296-65 WAC addresses asbestos removal and encapsulation.

13.2 Protection from Trespassers

Water facility design should include locks on all hatches, access entries, site fences, and ladder extensions to prevent unauthorized entry and vandalism, and protect water quality and public health. See WAC 246-290-235 for distribution reservoir protection requirements.

13.3 Heat Exchangers

Heat exchangers for heating or air conditioning (water-to-air or water-to-liquid) **must** have cross-connection protection (WAC 246-290-490). Returning water to the distribution system after it passes through a heat exchanger is prohibited (WAC 246-290-490(2)(k)).

13.4 Cross-Connection Control

Purveyors **must** protect water systems from contamination through cross-connections with nonpotable water or other liquids conveyed through piping (WAC 246-290-490). By definition, a water system includes any collection, treatment, storage, or distribution facilities *under control of the purveyor* (WAC 246-290-020). Thus, the purpose of a purveyor’s cross-connection control program is to protect the quality of water, delivered to the customer (at the service connection), from contamination through cross-connections (WAC 246-290-490).

DOH *does not* require purveyors to eliminate or control cross-connections that may exist within the property lines of individual customers. Requirements for plumbing and cross-connection control within the premises of individual customers are in the *Uniform Plumbing Code*. The *authority having jurisdiction* (usually the city or county building official) administers and enforces these requirements.

13.4.1 General Requirements

The purveyor’s cross-connection control program **must** meet the minimum elements of WAC 246-290-490.

- Purveyors **must** eliminate cross-connections or install approved backflow prevention assemblies (WAC 246-290-490(2)(f)).

- The type of assembly installed **must** be appropriate for the degree of hazard the customer's plumbing system poses to the purveyor's distribution system (WAC 246-290-490(4)(b)).
- Purveyors **must** isolate certain types of hazardous premises from the distribution system by installing an air gap or a reduced pressure backflow assembly (RPBA) at the service connection (see Table 9 in WAC 246-290-490(4)(b)).

There are special requirements for wastewater treatment plants and nuclear reactors.

Where DOH does not require premises isolation, the purveyor can rely on the customer's in-premises assemblies to protect the distribution system against contamination. The design engineer should work with the purveyor to identify all existing and potential cross connections and provide adequate cross-connection protection for all new water system projects.

All backflow assemblies purveyors use for distribution-system protection **must** be models acceptable to DOH (WAC 246-290-490(5)). Assembly design, installation, and testing **must** follow WAC 246-290-490 and good engineering practices. Section 13.4.4 includes several recommended guidance manuals and explains how to obtain a list of DOH-approved backflow prevention assemblies.

Purveyors **must** coordinate cross-connection control issues with the building official (called the *authority having jurisdiction*) that administers the UPC (WAC 246-290-490(2)). To prepare construction documents consistent with the WAC and the water system's cross-connection control program, the design engineer should contact both the purveyor and the *authority having jurisdiction* to determine applicable cross-connection control requirements. A water system's program may be more stringent than the minimum requirements of WAC 246-290-490.

13.4.2 Cross-Connection Control Considerations for Water System Facility Design

The design engineer also **must** consider cross-connection issues when designing various water system facilities such as water treatment plants, disinfection facilities, pump stations and storage tanks (WAC 246-290-490(1)(d)). Section 12.9 includes additional guidance on cross-connection control for water treatment facilities. General water facility design considerations include, but are not limited to, ensuring:

1. Cross connections between finished and raw water in a water treatment plant are eliminated or controlled.
2. Pipes are color coded or labeled to avoid accidental cross connections in future piping changes.
3. Atmospheric or pressure vacuum breakers protect all hose bibbs and similar fixtures associated with system facilities.
4. Backflow preventers protect the water supply from buildings with chemical feeders.
5. Overflow and drain pipes from storage tanks drain to daylight.
6. Pump-to-waste piping from wells is fitted with an appropriate air gap.

7. Booster pump operations do not create low-pressure conditions elsewhere in the distribution system that may result in backsiphonage.
8. Water system appurtenances, such as blow-off and air/vacuum relief valves, are not vulnerable to flooding.
9. There are no direct connections between any water line and any wastewater line or facility. Purveyors should seek the right to review plans for wastewater utilities they serve.
10. Stop and waste valves are not used to provide seasonal drainage of the distribution system. Using them could cause contamination of the distribution system.
11. The operations and maintenance manual prepared for any project includes provisions for periodic inspection and/or testing of all backflow preventers.

Some backflow prevention assemblies might increase headloss. Typically, the engineer can expect a headloss of 4 to 6 psi across a double check valve assembly and 10 to 15 psi across a reduced pressure backflow assembly. If using these assemblies, the design engineer should account for this hydraulic penalty in the overall water system design (higher water system pressures may be necessary if using these assemblies). The appropriate headloss curves for backflow prevention assemblies are in the manufacturers' specification sheets.

13.4.3 Technical Information

Approved Backflow Assemblies List and Technical Assistance

Backflow prevention assemblies used for cross-connection control **must** be acceptable to DOH (WAC 246-290-490(5)). The University of Southern California (USC) Foundation for Cross-Connection Control and Hydraulic Research allows DOH to reformat and reproduce its list of approved assemblies. DOH issues *Backflow Prevention Assemblies Approved for Installation in Washington State* (DOH 331-137) on CD once a year with updates during the year, as needed. You can order the CD on our Web site (see Appendix A) or by contacting the DOH regional office (see Table 1.1).

If you are a member of the foundation, you can access the list directly from the USC Web site (see Appendix C).

For technical assistance, see Appendix C or contact the DOH regional office (see Table 1.1).

Guidance Manuals

- You can order the following guidance manuals directly from the publishers (see Appendix C):
- *Manual of Cross-Connection Control, 9th Edition*, published by the USC Foundation for Cross-Connection Control and Hydraulic Research.
- *Cross Connection Control: Accepted Procedure and Practice Manual, 6th Edition*, published by the Cross-Connection Control Committee of PNWS AWWA.

- *Cross-Connection Control for Small Water Systems,* published by DOH (DOH 331-234).
- *Recommended Practice for Backflow Prevention and Cross-Connection Control, AWWA Manual M14, 3rd Edition,* published by AWWA.

13.5 Seismic Design

In an earthquake, moderate to severe ground motion in some regions may cause significant damage to vulnerable water system components, such as connections to reservoirs and chemical container tie-downs. Engineers **must** consider seismic risk when designing waterworks structures. Designs for all waterworks structures **must** comply with the latest edition of the International Building Code or local codes and conditions, if they are more stringent (WAC 246-290-200).

The engineer should determine how susceptible soils are to liquefaction. The Department of Natural Resources, Geology and Earth Sciences Division recently completed liquefaction susceptibility maps and National Earthquake Hazards Reduction Program site class maps for all the counties in the state (Palmer et al. 2004). If the soils are highly liquefiable, the design engineer should follow the recommendations of a qualified geotechnical engineer.

13.5.1 Pipe Systems for Seismically Vulnerable Areas

Design engineers should carefully evaluate materials selected for pipelines in soils highly susceptible to liquefaction. They may need to seek the services of other professionals qualified to assist with the selection.

13.5.2 Seismic Design Criteria for Reservoirs

All reservoir designs **must** comply with the latest edition of the *International Building Code,* and the most recent AWWA standards for reservoirs. Engineers **must** consider seismic risk when designing reservoirs (WAC 246-290-200). All piping connections to tanks, standpipes, and reservoirs should be flexible.

If there is sufficient freeboard to allow “sloshing” of the tank or reservoir contents, the engineer may use the effective-mass design method. Purveyors **must** anchor all ground-supported flat-bottom tanks to appropriately designed reinforced concrete bases with connectors able to withstand a combination of uplift and shear. Tanks containing fire-suppression water **must** meet the *International Building Code* or AWWA Standard definition for an occupancy category of “essential facility.” Detailed design guidance for welded steel tanks (D-100), bolted steel tanks (D-103), and wire-wound circular pre-stressed-concrete water tanks (D-110) are in the AWWA Standards.

13.5.3 Mechanical Seismic Restraint Design

For mechanical seismic restraint design, DOH recommends the Sheet Metal and Air Conditioning Contractors National Association's (SMACNA) *Seismic Restraint Manual Guidelines for Mechanical Systems (SMACNA 1998)* and the Seismic Restraint Design Chapter of the latest edition of the American Society of Heating, Refrigeration, and Air-Conditioning Engineers *HVAC Applications Handbook (ASHRAE 2003)*.

References

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Chapter 14: Construction Inspection and Final Approval

DOH requires purveyors and engineers to inspect water system projects before they serve water to the public. This chapter discusses the tests and procedures purveyors and engineers must use to prove water system improvements meet DOH-approved construction standards and specifications.

14.1 Construction Completion Report

Purveyors **must** submit a *Construction Completion Report Form* (DOH 331-121) to DOH within 60 days after they complete a project requiring DOH approval, and before they place the project into service (WAC 246-290-120(5)). This includes any source, water quality treatment, storage tank, booster pump facility or distribution projects.

An engineer, licensed in Washington, **must** complete and sign the form (WAC 246-290-040). The form requires the engineer to certify that the installation, disinfection procedures, pressure test results, and bacteriological sampling results comply with DOH-approved construction standards and specifications.

The *Construction Completion Report Form* (DOH 331-121) is online (see Appendix A).

14.2 Water Facilities Inventory Form

To reflect construction changes or additions, DOH **requires** water systems to submit an updated *Water Facilities Inventory Form* with the *Construction Completion Report Form* (DOH 331-121) (WAC 246-290-120(6)). This form is available from DOH regional offices (see Table 1-1).

14.3 Pressure and Leakage Test

To check the quality of joints and fittings used to construct distribution and transmission pipes, purveyors **must** always conduct a pressure and leakage test (WAC 246-290-120(5)(b)). The test **must** follow the testing procedure the engineer specified in the DOH-approved construction documents. The project engineer or the engineer's representative should be present during this critical test to verify it meets the specifications. Common pressure testing standards are AWWA C600, AWWA C605, and WSDOT/APWA (AWWA 1994, AWWA 1999, and WSDOT/APWA 2008).

14.4 Disinfection

Purveyors **must** properly disinfect any addition or modification to the water supply before using it (WAC 246-290-451(1)). DOH expects this disinfection meet the specifications approved for the water system, such as AWWA C651 for water mains (AWWA 1999b) and AWWA C652 for water storage facilities (AWWA 2002).

14.5 Disposal of Chlorinated Water and Dechlorination Practices

To avoid environmental affects, particularly those that could harm aquatic life, water systems must dispose of chlorinated water properly. Acceptable ways to dispose of chlorinated water include:

- **Prolonged storage.** Let it naturally dissipate through prolonged storage or other means (providing no potential for an environmental problem).
- **Discharge to a sanitary sewer.**
- **Dechlorination.** Use a reducing chemical, such as sodium thiosulfate, sodium bisulfate, sodium sulfite, sulfur dioxide or ascorbic acid (Vitamin C). Strategically place porous sacks or other suitable containers filled with sodium thiosulfate in the discharge water. Metering pumps are best for long-term dechlorination jobs. Chemical feeders have the advantage of precise metering of neutralizing agents. Aeration using submerged or spray aerators eliminates only minor amounts of chlorine residual and, therefore, is not an effective dechlorination practice. Specific details on dechlorination practices are in AWWA standards (AWWA 1999b; AWWA 2002).

Before discharging chlorinated water to the environment, the contractor or utility should check with the:

- Local sanitary sewage, surface water or drainage agency.
- Department of Ecology.

14.6 Microbiological Test

For new construction, water systems **must not** provide drinking water to consumers until a state-certified lab reports satisfactory results (WAC 246-290-451(1)). The engineer **must** note the satisfactory test results on the *Construction Completion Report Form* (DOH 331-121) (WAC 246-290-120(5)). To ensure the samples properly represent water quality in the water system, purveyors should not take water samples before sufficiently flushing the new lines or equipment.

14.7 Construction Inspection

Construction inspection and final closeout activities will vary depending on the size and complexity of the construction project. The following sections include lists of items that engineers or their designees should check before they certify a project as complete. These lists are only a starting point. Engineers should develop their own construction inspection lists for their particular projects.

14.7.1 Pipelines

During construction, DOH recommends engineers check the following elements, plus others appropriate to their specific projects:

1. Pipe material and size.
2. Coatings or linings meet specifications.
3. Bedding and backfill considerations including materials, quantities, placement, and compaction.
4. Depth of burial and location relative to possible sources of contamination.
5. Distance and direction to other pipelines, especially pressurized sewer lines and natural gas lines.
6. Size and location of thrust blocks or other pipe restraint systems.
7. Type, installation, and location of all isolation and control valves.
8. Location and description of all appurtenances.
9. Proper operation of cathodic protection systems, if installed.

14.7.2 Storage Reservoir Inspection

During construction, DOH recommends engineers check the following elements, plus others appropriate to their specific projects:

1. Material and thickness of coatings or paint systems and ANSI/NSF Standard 61 certification.
2. Curing time and conditions for coatings before instituting service.
3. Satisfactory results from other material-related water quality testing per DOH guidance or policy (see Appendix H). This is to verify proper use of materials and curing.
4. All appurtenances located and attached per specifications.
5. All openings sealed, locked, or screened per specifications.
6. Structural and foundational requirements met.
7. Acceptable leakage testing results.
8. Proper disposal of water following state or local disinfection regulations.
9. Performance testing of tank level control system and the tank alarm system.

14.7.3 Inspecting Pumps and Controls

During construction, DOH recommends engineers check the following elements, plus others appropriate to their specific projects:

1. All pumps work at prescribed on-off settings.
2. Flow rates match pump curves at system pressures.
3. Alarms work at specified settings.
4. Automatic and manual controls work as specified.
5. Acceptable pressure testing results.

14.7.4 Treatment System Inspection

During construction, DOH recommends engineers check the following elements, plus others appropriate to their specific projects:

1. Filter media and chemicals used as specified.
2. Proper depth and composition of media.
3. The performance and control of the treatment unit complies with the criteria specified for final acceptance.
4. Requirements for any ripening or stabilization period have been met.
5. Redundant and backup components, as well as primary components, are checked against performance standards and comply with specifications.

14.8 Change Orders

Engineers **must** submit "significant" change orders on the approved construction documents to DOH for approval (WAC 246-290-120(4)(d)). A list of changes DOH considers significant is in Section 3.4. Engineers should attach a description of non-significant change orders to the *Construction Completion Report Form* (DOH 331-121).

14.9 Documentation When DOH Approval is not Required

Purveyors with a current approved water system plan that includes standard construction specifications for distribution are not required to seek further approval of engineering documents for distribution mains in their approved service area (WAC 246-290-125(2)). However, the purveyor that exercises this option still must keep a *Construction Completion Report Form for Distribution Main Projects* (DOH 331-147) on file for DOH review at a later date (WAC 246-290-125(2)).

Detailed requirements for the submittal exception process are in Chapter 4 and WAC 246-290-125. The *Engineering Design Review Report Form* (DOH 331-122) and *Construction Completion Report Form* (DOH 331-121) are on the DOH Web site (see Appendix A).

14.10 Record Drawings

The engineer who manages construction or inspection typically provides record drawings to the purveyor when the project is complete. The purveyor **must** maintain a complete set of record drawings and provide them to DOH upon request (WAC 246-290-120(4)(e)).

References

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Appendix A: Department of Health Drinking Water Forms, Checklists, Policies and Procedures

A. 1 Forms

You can obtain DOH forms for drinking water projects by contacting the DOH regional offices listed in Table 1-1. The forms referenced in this manual are online at <http://www.doh.wa.gov/ehp/dw/forms/forms.htm>.

For persons with disabilities, forms are available on request in other formats. To submit a request, call (800) 525-0127 (TTY 1-800-833-6388).

A.2 Policies and Procedures

DOH Office of Drinking Water policies are online at <http://www.doh.wa.gov/ehp/dw/ODW-policy.htm>. Call Policy and Finance staff at (360) 236-3100 if you have questions about these policies or procedures.

A. 3 Checklists

Checklists can help you determine if minimum design requirements are met. On the following pages, you will find various Project Submittal Checklists that can be used to prepare submittals for review by DOH staff or third parties.

Project Checklists
Washington State Department of Health

The purpose of these project checklists is to ensure a complete and properly organized project submittal to DOH or third party for review under the submittal exception process for distribution-related projects.

Failure to comply with the minimum requirements could result in the project submittal being returned. Incomplete submittals will always result in a delayed project review due to the time required to receive the missing information.

The most recent edition of the following reference documents should be consulted when preparing project submittals:

- Group A Public Water Supplies, chapter 246-290 WAC
- DOH Water System Design Manual (DOH 331-123)
- DOH Water System Planning Handbook (DOH 331-068)
- DOH Water Use Efficiency Guidance (DOH 331-375)
- Recommended Standards for Water Works
- AWWA Standards
- APWA/WSDOT Standard Specifications for Road, Bridge, and Municipal Construction
- Minimum Standards for Construction and Maintenance of Water Wells, WAC 173-160
- Local Coordinated Water System Plan, if applicable

Standard Project Submittal Requirements

A standard project submittal will be one of three types of documents:

1. Water System Plan
2. Project Report
3. Construction Documents

Plus, these three forms:

1. Project Approval Application
2. Project Checklist
3. Construction Completion Report

In addition, if the project involves approval of a new source, increased water system physical capacity, or increase in the approved number of connections, then a completed *Water Right Self-Assessment Form* must also be included in submittal package.

The specific content of these documents and forms, and exceptions to these requirements is defined in WAC 246-290 and is summarized below.

Water system plan as defined in WAC 246-290-100. The purpose of the water system plan is to establish a uniform process for identifying present and future needs and set for a means for meeting those needs. The water system plan must address all items defined in WAC 246-290-100. The following categories of community water systems must develop a water system plan:

- All water systems with 1,000 or more services.
- Water systems located in areas utilizing the Public Water System Coordination Act (70.116 RCW).
- Any water system experiencing problems related to planning, operation, or management as determined by DOH.
- Any expanding Group A water systems.
- Any Group A water system for which a change in ownership is proposed.
- All new Group A water systems.

DOH will not consider project reports and construction documents submitted for approval by purveyors required to have a water system plan (WAC 246-290-110 and 120) unless there is a current approved water system plan that adequately addresses the project.

Project Report as defined by WAC 246-290-110. The purpose of the project report is to document the reasons why the project is being constructed. The project report must address all items defined in WAC 246-290-110. If the project is intended to increase the number of approved connections for a water system, the project report **must** also include an analysis of the physical capacity of the water system and water rights.

If the water system has an approved water system plan, the project report must identify the project's relationship to the water system plan. Relevant planning information need not be duplicated in the project report.

Construction Documents as defined by WAC 246-290-120. The purpose of the construction documents is to show how the project will be constructed.

Project Approval Application. The purpose of the Project Approval Application is to identify the project applicant and design engineer. It also acknowledges that the applicant knows the size of water system and type of project being submitted. DOH uses this information to determine the review and approval fees.

Project Checklist. The purpose of the project checklist is to ensure a complete and properly organized project submittal to DOH or third party for review. The checklist must be completed for all distribution-related projects under the submittal exception process.

Water Right Self-Assessment Form. The purpose of the *Water Right Self-Assessment Form* is to identify the water right information necessary for DOH to review and approve construction documents and project reports. The *Water Right Self-Assessment Form* will be forwarded to the Department of Ecology for review. Water system projects for a new source or increased water system capacity that require DOH approval must have adequate water rights before they can proceed. Increased water system capacity includes any approval that will result in additional water usage by the water system.

Construction Completion Report as defined by chapter 246-290 WAC. The purpose of the construction completion report is to document that the project has been constructed according to the DOH-approved plans and specifications. This form must be completed and submitted to DOH within 60 days of completion and before use of any storage tank and booster pump facility and other distribution-related projects approved for construction by DOH. Other distribution-related facilities designed by a professional engineer, but not required to be submitted to DOH for approval must all have a construction completion report on file with the water system.

DOH has developed a project checklist covering each of the project types listed below:

I. General
II. Source of Supply
III. Reservoirs and Storage Tanks
IV. Booster Pump Stations
V. Pressure Tanks
VI. Transmission and Distribution Mains
VII. Hydraulic Analysis
VIII. Water Treatment Facilities

Only applicable sections of the project checklist need to be completed.

I. General Design Checklist

All project reports and construction documents **must** include:

- ☐ Engineer's stamp.
- ☐ Narrative discussion that establishes the need for the project. It should include recommended alternative construction schedule, project cost and method of financing. Also, indicate the relationship of the project to the water system plan either currently approved or in the process of being prepared or updated.
- ☐ Alternative analysis and rationale for selecting the proposed project. It should include an evaluation of life cycle costs taking into account initial costs and on-going operations and maintenance costs.
- ☐ Planning considerations must be provided by either citing appropriate reference in an approved water system plan or included as part of the project report.
- ☐ Site map including easements, topographical contours, and proper site drainage.
- ☐ Analysis of the capacity of the water system if the project is intended to increase the physical capacity of the water system. Rationale and calculations to justify total number of service connections and equivalent residential units (ERUs) the water system is able to serve should be provided. The analysis should identify the number of residential, industrial, commercial, and municipal connections presently served by the water system.
- ☐ *Water Right Self-Assessment Form* must be completed for new sources and all projects that increase water system capacity or the approved number of connections.
- ☐ Hydraulic analysis that demonstrates the ability of the project to supply minimum pressure requirements during peak flows and fire events. The analysis should include a narrative discussion that describes the hydraulic analysis method, explains critical assumptions, and summarizes the effect of the proposed expansion on the existing water system.
- ☐ Measures to protect against vandalism should be described.
- ☐ Disinfection procedures according to AWWA or APWA/WSDOT standards. A narrative discussion on how the project will be disinfected and tested prior to use.
- ☐ Provisions to discharge water to waste including description of how wastewater is disposed, and documentation that procedures are acceptable to the Department of Ecology and local authorities.
- ☐ Routine and preventive maintenance tasks and frequencies need to be adequately addressed in a water system plan for the new facility or included in a project report. Operation costs related to the project should also be discussed along with an evaluation of requirements for certified operator.

Note: *Refer to Chapters 2, 3, and 4 and WAC 246-290-110 and 120 for additional guidance.*

II. Source of Supply Checklist

Source of supply project reports and construction documents **must** include:

- ☐ Formal alternative comparison and rationale for selecting proposed project.
- ☐ Water right permit, certificate or claims issued by the Department of Ecology, including completed *Water Right Self-Assessment Form*.
- ☐ Source of supply analysis that justifies the need for a new or expanded source of supply.
- ☐ Copies of legal documents (easements or covenants) for the sanitary control area (WAC 246-290-135).
- ☐ Map of the site and vicinity including well location (both township/range and latitude/longitude), pump house, water lines, site topography, sanitary protection area, and location of potential sources of contamination including septic systems, sanitary sewers, buildings, roads, and driveways.
- ☐ Susceptibility assessment per WAC 246-290-135.
- ☐ Site piping plans including:
    - Source meter
    - Valving
    - Sample taps for raw and finished water
    - Location, size, type and class of pipe
- ☐ Pump house details including pump control logic, emergency alarm systems, casing and pump house slab elevations, water level measuring device, and electrical connections to allow the use of emergency power.
- ☐ Pumping equipment specifications including:
    - Horsepower, GPM, head, pump controls, and alarm system.
    - Specific pump curve being used and operation range of head and flow conditions clearly indicated on pump curve.
    - Narrative discussion of ability of the source and pumping system to supply peak daily water volumes.
- ☐ Source pump control and pump cycle protection. Refer to Chapter 11 for pressure tank sizing requirements and Chapter 9 for appropriate pump control levels for reservoirs.
- ☐ Water quality test results for each source, including:
    - Bacteriological/coliform test (bacti/coli)
    - Inorganic chemical and physical analysis (IOC)
    - Radionuclide test (only required for community water systems)
    - Volatile organic chemical (VOC) test
    - Synthetic organic chemical (SOC) test, unless demonstrated that source can meet DOH's requirements for monitoring waiver
    - Results of any other tests required due to site-specific concerns

If treatment is required, refer to the checklist in this section and other applicable sections of this manual for guidance regarding design of treatment facilities.

If groundwater:

- Well site inspection made by the DOH or local health jurisdiction.
- Well construction details including general design and construction standards, casing specifications, general sealing requirements and material specifications, screened inverted vent, and access port of measuring water level.
  Note: *Pitless units or adapters must comply with design standards in DOH policy, "Pitless Adapters and Watertight Well Caps."*
- Well log including unique well identification tag number, surface seal, depth to open interval or top of screened interval, overall depth from well the top of the casing, and elevation of top of casing.
- DOH pump test results following procedures in Appendix E.

If groundwater or spring source:

- Wellhead Protection Program Plan as required under WAC 246-290-135.

If surface water or groundwater under the direct influence of surface water (GWI):

- Watershed Control Program Plan as required under WAC 246-290-135.

Note: *Refer to Chapter 7 and WAC 246-290-130 and 135 for further guidance.*

III. Reservoir and Storage Tank Checklist

Reservoir and storage tank project reports and construction documents **must** include:

- ☐ Sizing analysis based on the combined volume of operating, equalizing, standby, and fire suppression requirements, including documentation of nesting standby and fire suppression storage, if applicable. Adequate tank freeboard must also be provided.
- ☐ Plans and specifications for storage tanks and reservoirs according to applicable design standards, including OSHA and WISHA requirements.
- ☐ Site feasibility considerations including documentation that adequate geotechnical analysis has been conducted.
- ☐ Base and overflow elevations identified including narrative justification regarding water system hydraulics and a description of the level control system with specific control levels identified.
- ☐ Storage construction details including:
  - Inlet and outlet
  - High- and low-level alarms
  - Locked access hatch
  - Screened vent
  - Screened drain with silt-stop
  - Local level indicator
  - Access ladders
  - Screened overflow
- ☐ ANSI/NSF Standard 61 certification of coatings, liners or other materials, if any, that would be in substantial contact with potable water. Application procedures for coatings should be specified in plans and specifications.
- ☐ Site piping plans including:
  - Reservoir isolation valving
  - Sample taps
  - Location, size, type, and class of pipe
- ☐ Leakage testing procedures per AWWA: A narrative discussion of how the tank will be tested for leaks.
- ☐ Disinfection procedures specified and related bacteriological sampling conducted prior to use.
- ☐ Water quality considerations including means to maintain water circulation and prevent stagnation.
- ☐ Procedures to test water quality, taste and odors prior to use.

Note: *Refer to Chapter 9 and WAC 246-290-235 for further guidance or requirements.*

IV. Booster Pump Station Checklist

Booster pump station project reports and construction documents **must** include:

- ☐ Sizing analysis, including pumping system discharge capacity requirements, as well as fire flow requirements, if any.
- ☐ Hydraulic analysis that demonstrates the ability of the project to meet minimum pressure requirements during peak hourly demands and maximum day demands plus fire flow. The analysis should include a narrative discussion that describes the hydraulic analysis method, explains critical assumptions, and summarizes the effect of the proposed expansion on the existing system (see Checklist VII Hydraulic Analysis for additional details).
- ☐ Service area map designating specific properties to be served.
- ☐ Pumping equipment specification including:
  - Horsepower, flow rate (gpm), head, pump controls, and alarm system.
  - The specific pump curve used and operation range of head and flow conditions must be clearly indicated on pump curve. A narrative discussion of the ability of the pumping system to meet required demands should be included.
- ☐ Pump house details including equipment layout, slope, and texture of pump house floor. Also, identify heating, cooling, and ventilation needs.
- ☐ Structural details including special anchoring or support requirements for equipment and piping.
- ☐ Control and instrumentation specifications including potential for surge or "water hammer."
- ☐ Site piping plans including:
  - Sample tap(s)
  - Isolation valves on the suction and discharge sides
  - Flexible couplings
  - Check valves on the discharge side
  - Surge anticipation valves, as needed
  - Suction side pressure gauge(s)
- ☐ Provisions for backup power to be evaluated and must be installed for all closed system booster pump stations.

Note: *Refer to Chapter 10 and WAC 246-290-230 for additional design considerations.*

V. Pressure Tank Checklist

Pressure tank projects reports and construction documents **must** include:

- ☐ Sizing analysis including withdrawal capacity (for example, the volume that can be withdrawn between pumping cycles).
  Note: *No equalizing storage credit given for Group A water systems.*
- ☐ Pressure settings including a narrative justification regarding water system hydraulics and operating pressure range.
- ☐ Plans and specifications for pressure tank, including air compressors, air release, air filter, and sight glass.
  Note: *If greater than 120 gallons, tank must be ASME approved. All pressure tanks must have an ASME code pressure-reducing valve.*
- ☐ Site piping plans including sample tap, and location, size, type, and class of pipe. Adequate space provided around the tank for operations and maintenance.
- ☐ ANSI/NSF Standard 61 certification of coatings, liners or other materials in contact with potable water, if any. Application procedures should be specified on plans and specifications.
- ☐ Procedures to test water quality, taste and odors prior to use.

Note: *Refer to Chapter 11 for additional design considerations.*

VI. Transmission and Distribution Main Checklist

Transmission and distribution main project reports and construction documents **must** include:

- ☐ Water system sizing analysis documenting availability of adequate source and storage to serve the proposed service area.
- ☐ Hydraulic analysis used to size mains and determine that required pressures can be maintained and hydraulic transient analysis for transmission mains and distribution mains where warranted by high pressures or high velocities (see Checklist VII Hydraulic Analysis for additional details).
- ☐ Identification and description of proposed land use within project area, including lots for new distribution system serving plats and subdivisions.
- ☐ Service area map designating specific properties to be served.
- ☐ Distribution system map showing location of water lines, pipe sizes, type of pipe, pressure zones, easements, and location of control valves, hydrants, meters, and blow-off valves.
- ☐ Specifications for materials, construction, depth of pipe bury, pressure and leakage testing.
- ☐ Adequate separation from sewer mains, nonpotable conveyance systems, and other buried utilities.
- ☐ Details for pipeline trench, service connections, air and vacuum relief valves, pressure-reducing valves, thrust blocking, backflow assemblies, fire hydrants, and other system appurtenances.

Note: *Refer to Chapter 8 and WAC 246-290-230 for additional considerations.*

VII. Hydraulic Analysis Checklist

A hydraulic analysis **must** be used to size and evaluate new, or expanding to existing, distribution systems. An acceptable hydraulic analysis includes:

- ☐ Description of model whether steady state, or extended period simulation.
- ☐ Assumptions are described including:
  - Allocation of demands
  - Friction coefficients, which will vary with pipe materials and age
  - Pipe network skelatonization, as appropriate
  - Operating conditions (source, storage booster pumps, valves)
- ☐ Minimum design criteria are met, including:
  - Peak hourly demand: 30 psi or greater when equalizing storage has been depleted (Section 8.1.5).
  - Maximum day demand plus fire flow: 20 psi or greater when equalizing storage and fire flow storage have been depleted (Section 8.1.5).
  - Static pressure of 100 psi or less when reservoirs are full (Section 8.1.7).
  - Transmission main pressure 5 psi or more, except adjacent to storage reservoirs (Section 8.1.5).
  - Maximum pipe velocity: 10 ft/sec or less in transmission mains (Section 8.2.4) and 8 ft/sec or less in distribution mains (Section 8.1.6). If not, include hydraulic transient analysis.
- ☐ Demand scenarios are described, including:
  - Current demand
  - Projected 6 year demand
  - Projected build-out demand of small water systems
- ☐ Provide copies of input and output, including:
  - Input data, (demands, elevations, friction losses, and pump curves)
  - Hydraulic profile
  - Node diagram
  - Printout of significant runs
- ☐ Model calibration meets criteria in Section 8.2.2 and Table 8-1.
- ☐ Summary of results, deficiencies and conclusions including:
  - Identification of deficiencies addressed in a capital improvement plan.
  - Locations in distribution system where pressures exceed 80 psi (Section 8.5.7).
  - Hydrant flow and placement on undersized mains.
  - Fire flow reliability, if applicable. The Water System Coordination Act (chapter 70.116 RCW) requires water systems that serve more than 1,000 connections or that are located in a critical water supply service area to meet certain reliability standards when fire flow is provided by pumping (see WAC 246-293-660).

Note: *Refer to Chapter 8 and WAC 246-290-230 for additional design considerations.*

VIII. Water Treatment Facilities Checklist

Before any significant work begins, the engineer should contact the appropriate DOH regional engineer (see Table 1-1). Pilot studies are generally required.

Additional checklists for iron and manganese removal, hypochlorination facilities, sodium fluoride saturators, and desalination of seawater or brackish water are located in Appendix G.

Water treatment facility project reports and construction documents **must** include:

- ☐ Narrative discussion describing water quality problem and type of treatment proposed.
- ☐ Analysis of alternatives, including a review of raw water quality information and a sufficiently detailed analysis of treatment alternatives to justify the selected process.
- ☐ Pilot study plan, as required.
- ☐ Pilot study report, as required.
- ☐ Raw water quality and pilot study water quality test results.
- ☐ Detailed design criteria and calculations to support the proposed treatment process, process control, and process utilities.
- ☐ Specifications for materials and equipment for the treatment facility.
- ☐ ANSI/NSF Standard 61 certification of coatings, liners or other materials, if any, that would be in substantial contact with potable water. Application procedures should be specified in the plans and specifications.
- ☐ Performance standards for water treatment facility based on effluent water quality.
- ☐ Building details including equipment layout, and heating, cooling and ventilation needs addressed.
- ☐ Site piping plans including raw and finished water sample taps installed.
- ☐ Methods and schedules for start-up, testing, and operation of the completed treatment facility.
- ☐ Provisions to dispose of solid waste material from treatment process, including description of how waste is to be properly disposed, and documentation that procedures are acceptable to the Department of Ecology and local authorities.

When the source is surface water, or confirmed to be groundwater under the direct influence of surface water, submittals **must** meet the following additional requirements:

- ☐ Disinfection analysis such as a tracer study to determine that adequate disinfection can be provided.
- ☐ Filter design details including the filter-loading rate and backwash design.
- ☐ Turbidimeter locations including those for individual filter turbidimeters and a combined filter effluent turbidimeter prior to the clearwell.

- Filter-to-waste design including an adequate air gap and properly sized waste pipe.
- Alarms for critical process control elements such as water levels, coagulation, filtration, and disinfection. Alarms must be set to provide sufficient warning to allow operators to take action or shut the plant down as appropriate.
- Standby equipment for critical processes such as coagulation, filtration, and disinfection to ensure that the plant can operate continuously.
- Multiple filtration units to allow for major maintenance and repairs on the filtration units. Complete redundancy for peak design flows does not need to be provided.
- Detailed Operations Program (O&M manual) detailing how the treatment facility will be operated. The document must describe:
  - Coagulation control methods
  - Chemical dosing procedure
  - Each unit process and how it will be operated
  - Maintenance programs for each unit process
  - Treatment plant performance monitoring
  - Laboratory procedures
  - Records
  - Reliability features
  - Emergency response plans, including ones for treatment process failures and watershed emergencies

Note: *For additional guidance, refer to Chapter 12, WAC 246-290-250, chapter 246-290 WAC Part 6, and DOH publications.*

Appendix B: Copies of Selected Guidelines Referenced

Well Field Designation Guideline

Subject: Definition of "well field" with notes on monitoring requirements for well fields

Purpose: Provide a definition of well field to help DOH staff determine utility compliance with inorganic and organic water quality monitoring

The Department of Health (DOH) recognizes the concept of considering nearby wells drawing from the same aquifer as a well field, and eligible for consideration as a single source when determining compliance with water quality monitoring requirements. This guidance to staff should ensure consistency when dealing with well field designations for Washington State water systems.

DOH may consider two or more individual wells a well field if <u>all</u> of the following criteria are met:

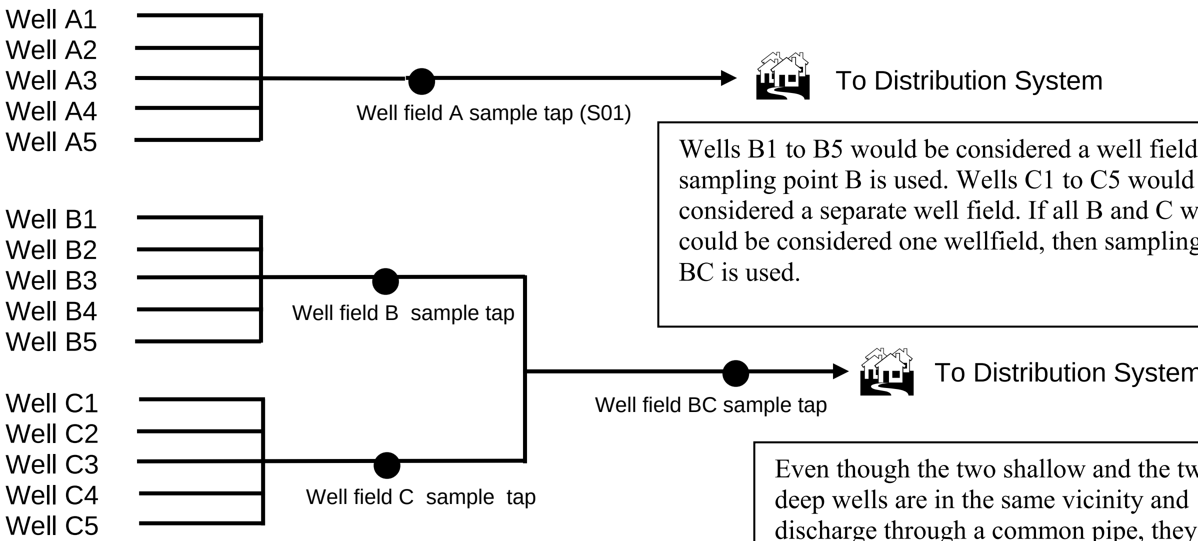
1. The depth of all individual wells must be within 20 percent of each other after taking wellhead elevation differences into account. The depth of the well shall be the distance from the top of the well to the well screen(s), perforations, or the water bearing strata.
2. All individual wells shall draw from the same aquifer(s) as determined by comparable inorganic chemical analysis (such as conductivity, total hardness, nitrates, chlorides or other information acceptable to DOH), or an evaluation of the well logs or water well reports for all of the wells being considered..
3. All individual wells must discharge water through a common pipe with a sampling port where a sample that includes water from all the individual wells within the well field can be collected. There shall be no individual service connections prior to the well field sampling point.
4. All individual wells must be under the control of the same purveyor to be considered part of a well field.

The following monitoring requirements apply to all designated well fields:

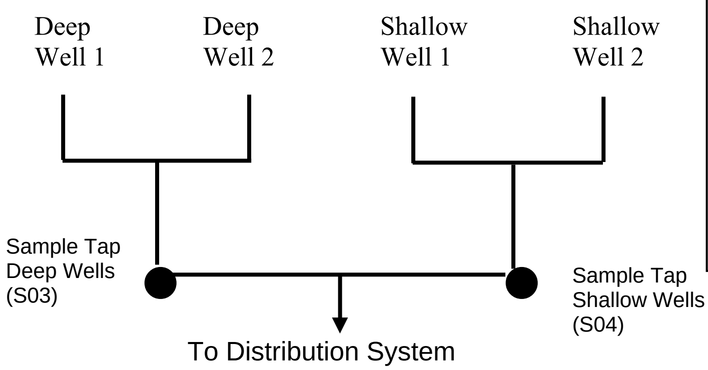
a. All individual wells, which are normally in operation during the sampling month, must be pumping when collecting a source sample.
b. Samples from a designated well field cannot be composited with samples from any other drinking water sources.

The water system purveyor shall provide the necessary information to justify varying from this guideline. DOH regional staff must concur with all variances from this guideline.

Well Field Examples

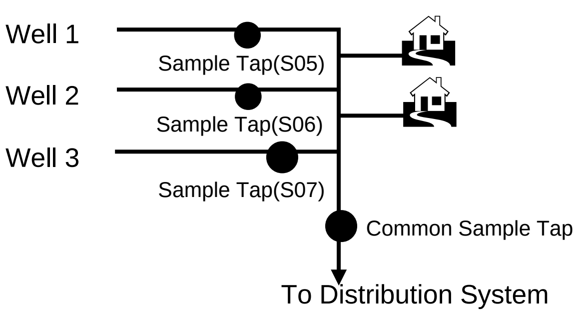


Wells B1 to B5 would be considered a well field if sampling point B is used. Wells C1 to C5 would be considered a separate well field. If all B and C wells could be considered one wellfield, then sampling point BC is used.



Even though the two shallow and the two deep wells are in the same vicinity and discharge through a common pipe, they cannot be considered one well field because they are of different depth and draw from different aquifers.

If the two deep wells can be piped so that there is a common discharge point for sampling, as shown, the two deep wells could be considered a well field. The same rule would apply to the two shallow wells.



Even if wells 1, 2, and 3 are the same depth and are in the aquifer, they cannot be considered a well field because there are service connections before a common discharge point (common sample tap)

Composite Sampling

DOH Source Code	PWS Source Name	Composite Samples
S01	Well Field A	Samples cannot be composited
S02	Well Field B (at sample tap BC)	Samples cannot be composited
S03	Well Field Deep Wells	Samples cannot be composited
S04	Well Field Shallow Wells	Samples cannot be composited
S05	Well 1	Samples can be composited for VOC and SOC monitoring
S06	Well 2	
S07	Well 3	

Secondary Contaminant Treatment Requirements and Options
Washington State Department of Health

This document helps to define the conditions that determine DOH requirements for secondary contaminant treatment (primarily iron and manganese treatment). It further addresses considerations on treatment requirements that may be imposed on a water system. “Treatment” means either removing a secondary contaminant from the source water or rendering a contaminant to reduce or eliminate its aesthetic effect (most often referred to as "sequestering" for iron and manganese treatment).

“The purveyor of any public water system providing service that has secondary inorganic MCL exceedances shall take follow-up action as required by the department. Follow-up action shall be commensurate with the degree of consumer acceptance of the water quality and their willingness to bear the costs of meeting the secondary standard. For new community water systems and new nontransient noncommunity water systems without active consumers, treatment for secondary contaminant exceedances will be required” (WAC 246-290-320(3)(d)).

Treatment by sequestering only be considered only if the combined iron and manganese levels are no more than 1.0 mg/l, and the manganese level is no more than 0.1 mg/l as Mn. If sequestering is considered for new sources, pilot testing to determine the appropriate treatment chemical dosage and treatment process requirements will be necessary. See Item III below for specific treatment considerations.

DOH will determine that a secondary contaminant problem may exist through evidence provided in customer complaints or by reviewing information provided by a purveyor. DOH will require action by the purveyor when the purveyor receives five or more specific complaints associated with a secondary contaminant from different customers in a 12-month period. DOH may receive the complaints individually or through a petition signed by five or more customers. When a problem is determined to be significant, the requirements below apply.

I. Iron and Manganese (Fe/Mn)

Compliance with the secondary standards for Fe/Mn is not required for water systems in existence prior to January 15, 1992, unless the iron or manganese is creating a “significant” problem as defined previously.

If a water system has a “significant” problem, it will be required to take the following actions:

1. The water supplier must prepare an engineering report with recommended corrective actions necessary to bring the water system into compliance with the Fe/Mn standards. The report must evaluate all reasonable alternatives and determine the costs associated with each alternative. The study must be prepared by a professional engineer registered in Washington State.
2. The results of the study conducted by the water supplier should be made available to the customer at an appropriately noticed public meeting, or by document distribution.

3. The water system must prepare a proposed survey of the regularly billed customers, which provides for questionnaires to be sent to each service connection to determine the customer preference regarding the quality of the water and the cost of compliance. The questionnaire should be as objective as possible and be based on the engineering report. The estimated capital and operation costs to the consumer should be based on the most cost-effective alternative presented in the engineering report. This alternative must also be acceptable to DOH.
4. The proposed survey questionnaire and the engineering report must be submitted to DOH for review and approval prior to its distribution.
5. Upon approval of the survey questionnaire, the water supplier must distribute it to the consumers. Customer responses to the questionnaire should be tabulated by the water system for submission to DOH.
6. Water systems that do not serve regularly billed customers similar to a community, will be reviewed and evaluated in a manner determined to be appropriate by DOH.

Special Allowances for Standby or Emergency Sources

Water systems may use existing untreated sources that exceed the MCLs for secondary constituents for standby service or to meet peak demands, without the need for an engineering report or customer survey, if all of the following occur:

1. The monthly production from such sources is metered and is not used for more than five consecutive days or a total of 15 days per year (use for any part of a day constitutes a day's use).
2. Secondary constituents do not generally exceed twice the MCL anywhere in the distribution system.
3. Public notification is made, with the notification being prior to use, whenever possible.

A. Basis for DOH Decisions

1. If the customer survey adequately demonstrates that most consumers (over 50 percent) that respond to the survey questionnaire do not wish to pay the costs necessary to attain compliance with the Fe/Mn standards, the water supplier may submit a written application requesting DOH to allow operation without treatment. DOH will then issue a letter, which states that treatment for iron or manganese will not be required. This allowance will be effective for five years beginning on the date of the letter.

   Note: *Although it would be desirable for all water system customers to respond to the survey, a 100 percent response rate is not expected. DOH considers that validation of the survey would require at least 50 percent of the total current customer base to respond to the survey. The purveyor must pursue this level of response to the extent that an additional survey questionnaire must be sent to all customers that did not respond to the* *initial survey if less than 50 percent of all customers responded. If, after the second survey, less than 50 percent of the customers respond, DOH will use a simple majority of the responses received to determine the treatment requirement.*

Whenever the survey shows clearly that more than 50 percent of all possible customers have stated either a willingness or unwillingness to pay for treatment, this information can be immediately presented to the state without waiting for additional customer responses.

2. At the end of the five-year period, DOH may re-evaluate the water system's status. The water supplier may be required to conduct a new survey if DOH determines that substantial changes have occurred (for example, a large increase in new customers or significant changes in water quality), which would warrant a re-survey of customers.

   Regardless of the five-year period covered by DOH's decision, the water supplier must re-survey its customers if DOH receives a petition signed by at least 25 percent of the water system's billed customers requesting a new survey. This will only be required, however, if a survey has not been conducted within the past 24 months.

B. Procedures for Enforcement

All water systems determined to be in violation of the standard for Fe/Mn may be issued a directive or, if needed, a department order to come into compliance with the standards, unless the criteria and procedures previously presented in this document are followed and DOH has determined that treatment is not warranted.

II. Other Secondary Contaminants

DOH will pursue action regarding secondary contaminants other than iron or manganese in a manner similar to that presented for iron and manganese. However, the degree of problem significance may vary. Depending on the constituent in question and the numbers and types of customer complaints, DOH will determine the most appropriate course of action on a case-by-case basis.

III. Treatment Considerations

Iron/Manganese Removal

When removal of iron or manganese is required, the most common method for removal employs oxidation followed by sedimentation and filtration. Oxidation may be affected by aeration, chlorination (chlorine or chlorine dioxide), or with use of potassium permanganate. Treatment is most effective at higher pH levels, usually in excess of pH 7.5. The best oxidant for manganese removal is potassium permanganate, which has been shown to be effective over wide ranges of pH.

Ion exchange technologies can also be used for Fe/Mn removal. With these methods, special care must be taken to ensure that the iron and manganese is not oxidized before application through the exchange media. Fouling of the exchange bed can occur if the iron or manganese is not maintained in a chemically reduced state.

Lime Softening processes can be used for iron/manganese removal, but this practice is normally used adjunct to water softening, which is not common in Washington State.

Treatment Waste Disposal

Wastes (for example, brine discharges or filter backwash wastewater) associated with treatment applications must be disposed of properly. The Department of Ecology should be contacted to determine the disposal requirements.

Iron/Manganese Sequestering

When sequestering (also called stabilization, chelation, or dispersion) is used as treatment method, certain limitations need to be recognized. Sequestering is not considered appropriate whenever the combined iron/manganese level is in excess of 1.0 milligram per liter (mg/L), with the manganese level being no more than 0.1 mg/l as Mn. In no case will sequestering be considered for combined iron/manganese levels above 1.0 mg/L, or when manganese levels are reported above 0.1 mg/l.

Addition of sequestering agents such as the polyphosphates (hexametaphosphate, trisodium phosphate) must be done prior to any oxidation influence. Concentrations of polyphosphate cannot exceed 10 mg/L as PO_4. The polyphosphate must be added at doses lower than those allowed under ANSI/NSF Standard 60 for the specific product.

Because polyphosphate is a bacterial nutrient and can lead to bacterial growth in distribution lines, disinfection must be applied following the sequestering treatment.

To prevent oxidation of the iron or manganese before they are stabilized, the polyphosphate should be added into, or near, the well on the suction side of the pump to minimize oxidation by aeration. The application point for the disinfectant should be more than 10 feet downstream of the pump discharge. A greater distance may be required by manufacturer's recommendations.

Sequestering agents are effective in cold water, but lose their capability in heated or boiled water. It should be recognized that this form of treatment may not resolve customer concerns for hot water portions of domestic service.

If it is determined that sequestering, after a year from its initiation as evidenced by complaints of the water system customers, is ineffective in eliminating a secondary contaminant problem, then removal treatment must be instituted.

Pilot Testing for Sequestering – Laboratory Bench Scale Tests

When sequestering is considered for iron/manganese control, the following process can be used to determine the dosage of sequestering agent needed for proper operation:

1. Treat a series of samples with a standard chlorine solution to determine the chlorine dose required to produce the desired chlorine residual.
2. Prepare a standard sequestering agent solution by dissolving 1.0 gram of agent in a liter of distilled water in a volumetric flask.
3. Treat a separate series of samples with varying amounts of the sequestering agent. One milliliter (ml) of the standard agent solution, prepared as per item 2 previously, is equivalent to a 0.1 percent solution. One ml of this stock solution in one liter of sample is equivalent to 8.34 pounds of sequestering agent per million gallons. Stir the various dosages to ensure good mixing in the series of samples; and continue to stir while adding the previously determined chlorine dosage to minimize creation of localized high chlorine concentrations.
4. Observe the series of treated samples against a white background to note the degree of discoloration. The proper dose of sequestering agent is will delay noticeable discoloration for a 4-day period.

Note: *Samples for the above bench test should be collected freshly, kept away from direct sunlight to avoid heating, and maintained at room temperature for the duration of the test.*

Notification Required

Whenever sequestering treatment is used for management of iron or manganese problems in a water system, the customers must be notified that this form of control is being used and that they may still experience problems with the hot water portion of their home plumbing. In addition, customers located in more remote portions of the water distribution system must be informed that iron/manganese may still pose a problem if their water is not routinely flushed through their lines. The form, method of delivery, and frequency for this notification will be determined in consultation with the Office of Drinking Water authority regarding secondary contaminants.

IV. Distribution System Related Problems

Occasionally, complaints about aesthetic concerns are not directly attributable to source water levels of iron or manganese. The water quality may be corroding the system distribution piping, leading to high iron levels at consumer taps. Some water systems may have problems associated with lengthy dead-end lines that are not flushed routinely. Existing water systems should examine the nature of any consumer complaints to determine if the problem is water source or distribution system related. The water purveyor should develop a report that identifies the nature of the problem and submit it to DOH for review. If distribution system corrosion is determined to be the problem, any treatment options examined to remediate the aesthetic concern should address ways to mitigate problems associated with water corrosivity.

Note: *Sequestering is not considered appropriate for distribution system related problems for either primary or secondary contaminants.*

Recommended References

AWWA and American Society of Civil Engineers (ASCE). 1990. *Water Treatment Plant Design*, 2nd Edition, Chapter 11: "Iron and Manganese Removal," McGraw-Hill. New York, NY.

HDR Engineering, Inc. 2001. *Handbook of Public Water Supplies*, 2nd Edition, Chapter 14: "Iron and Manganese Removal," John Wiley & Sons, New York, NY.

Sommerfeld, E.O. 1999. *Iron and Manganese Removal Handbook*, AWWA, Denver, CO.

Hydropneumatic Tank Sizing Associated with Cycle Stop Valves

A unique device, called a "cycle stop valve" (CSV), is manufactured by Cycle Stop Valves, Inc., located in Lubbock, Texas. This device is a modified pressure-reducing valve that maintains a constant downstream pressure over wide ranges in flows. It will maintain pressure until the flow goes to some prescribed low level, at which point the CSV will signal shut-off of the pump. A pressure tank is still needed with the CSV to accommodate the need for pump motor cycling control at the low flow settings. The sizing of this pressure tank will depend on the design setting pre-established for the CSV, but in all cases, the tank size will be less than that required if a CSV had not been installed.

The company maintains an extensive Web site <http://www.cyclestopvalves.com/> that gives information concerning the valve, its advantages, and general information on how they are to be used. There are several models, but for pressure tank design purposes, they can be divided into two categories:

- **Domestic/Commercial Series** with a minimum flow of 1 gpm and maximum of up to 60gpm, intended for private and small water systems.
- **Municipal/Agricultural Series** with a minimum flow of 5 gpm and a maximum of up to 10,000 gpm.

The manufacturers claim the following advantages when using CSVs in a pressurizing system:

1. They limit the cycling of pumps.
2. They reduce the size or number of pressure tanks required for any given installation.
3. They reduce water hammer at pump-on and pump-off conditions.

The CSV is installed between the pump(s) and the pressure tank(s) and pressure switch. The CSV pressure level is set at or above the pump-on pressure, but below the pump-off pressure. As the demand in the water system varies, the CSV adjusts the flow while maintaining a constant downstream pressure. In essence, the pump acts as a variable capacity pump whose output matches the water system demand on an instantaneous basis. Only when the demand drops below 1 or 5 gpm (depending on the size of the water system demands) would any of the pump output be available to recharge a pressure tank. Hence, the pump-on phase of the pump cycle will be extended until the demand drops below either the 1 or 5 gpm level. It also is apparent that, for larger water systems, where the demand (including leaks) never drops below the set-point of 1 or 5 gpm, the pump may be "on" indefinitely.

After the pressure tank fills up to its pump-off point, however, any demand by the water system must be met by the available withdrawal from the pressure tank, until the pressure falls to the "pump-on" level. The length of the "pump-off" period depends upon the water system demand and the available withdrawal volume of the pressure tank. The sizing of the tank, therefore, consists of determining both the:

- Probable water system demand during the pump-off period.
- Recommended length of time before the pump re-starts, for example, the pump-off period.

DOH recommends a minimum withdrawal volume of 10 times the minimum flow designed for the CSV, giving an estimated ten minutes of pump-off time when the demand is low before restarting. The manufacturer's Web site includes a page with technical information about the use of pressure tanks and a table showing suggested pressure tank sizes. Considering the DOH recommendation and manufacturer's suggestions, the following table shows the recommended pressure tank sizes.

	Domestic/- Commercial Series	Municipal/- Agricultural Series
Minimum Flow, gpm	1	5
Recommended Flow Range, gpm	1 – 60	5 – 10,000
Withdrawal Volume, 10 minutes at minimum flow, gallons	10	50
Estimated Minimum Gross Pressure Tank Volume (4 X withdrawal volume)*, gallons	40	200
Withdrawal Volume, as per manufacturer, for 5 to 20 connections	25	30
Estimated Gross Pressure Tank Volume as per manufacturer, (4 X withdrawal)*, gallons	100	120
Recommended Gross Pressure Tank Volume, gallons	100	200

* The estimated ratio of gross volume to withdrawal volume used in the foregoing table is based upon a pump-on/pump-off differential of 20 psi, with a low pressure not less than 30 psi, and a high pressure not exceeding 70 psi.

Considerations Associated with Use of CSVs

- Because pump-starting electrical energy demand is high, it would be advantageous to limit the number of "pump-start" events. However, it is difficult to predict whether the savings through limiting the number of such events and reduced initial capital cost will offset the additional energy used in prolonging the pump-on portion of the cycle.
- Water quality may affect CSV performance. It has been reported that water containing sand adversely affected the performance of the 1 gpm CSV.
- At low flow conditions, the pressure on the upstream side of the CSV could approach shut-off head of the pump, which could be very high. Attention should be paid to the design, material specifications and construction of this portion of the water system.

Appendix C: List of Agencies and Publications

Note: *This list contains the addresses and phone numbers for each agency's main office or location. Many of the agencies also have local or regional offices that offer services. This list of agencies and the information they provide is not intended to be all-inclusive.*

Agency Name	Mailing Address	Telephone and Web Site	Information or Publications Available
Federal Agencies			
U.S. Environmental Protection Agency (EPA) Region 10	1200 Sixth Avenue Seattle, WA 98101	(206) 553-1200 or (800) 424-4372 (general) (206) 553-8512 (drinking water) <http://www.epa.gov/r10earth/>	All topics related to the Safe Drinking Water Act
Health and Human Services, Region X Public Health Services	2201 Sixth Avenue Seattle, WA 98121	(206) 615-2469 <http://www.acf.hhs.gov/programs/region10/>	Fluoridation information
National Oceanic and Atmospheric Administration	7600 Sand Point Way NE Seattle, WA 98115	(206) 526-6087 (Weather Service) <http://www.wrh.noaa.gov/sew/> National Climatic Data Center <http://www.ncdc.noaa.gov/oa/ncdc.html>	Climate information
Occupational Safety and Health Administration (OSHA)	1111 Third Avenue, Suite 715 Seattle, WA 98101	(206) 553-5930 <http://www.osha.gov/>	Employee and construction safety

Agency Name	Mailing Address	Telephone and Web Site	Information or Publications Available
Washington State Agencies			
Office of Washington State Climatologist (OWSC)	University of Washington Box 354235 Seattle, WA 98195-4235	(206) 543-3145 <http://www.climate.washington.edu/>	Historical climate information
Department of Ecology Water Resources Program	300 Desmond Drive PO Box 47600 Lacey, WA 98504-7600	(360) 407-6600 (water rights and water quality) (360) 407-6700 (hazardous waste and toxics reduction) <http://www.ecy.wa.gov/> Publications: <http://www.ecy.wa.gov/biblio/>	-Water rights -Criteria for sewage works design -Disposal of chlorinated water -Dam safety -Well construction standards -Disposal of WTP backwash -Hazardous waste disposal
Department of Health Office of Drinking Water	PO Box 47822 Olympia, WA 98504-7822 See Table 1-1 for locations of DOH regional offices	(360) 236-3100 (800) 521-0323 <http://www.doh.wa.gov/ehp/dw/> Publications: <https://fortress.wa.gov/doh/eh/dw/publications/publications.cfm>	-Planning Handbook -Small Water System Management Program Guide -Conservation information -Group B Design and Approval Guideline -Fact sheets -Approved Backflow Assemblies List -Copies of policies and other guidelines -Drinking water rules -Technical assistance -Other information identified in the Water System Design Manual

Agency Name	Mailing Address	Telephone and Web Site	Information or Publications Available
Department of Labor and Industries (L&I)	WISHA Services PO Box 44600 Olympia, WA 98504-4600 Boiler and Pressure Vessels PO Box 44410 Olympia, WA 98504-4410	(360) 902-5800 (Main) (360) 902-5500 (WISHA) (360) 902-5226 (Plumbing and Contractor Registration) (360) 902-5270 (Boiler and Pressure Vessels) <http://www.lni.wa.gov/>	-Safety rules -Work in confined spaces -Working with asbestos-cement pipe -Statutes and rules on boilers and pressure vessels -Plumber certification and contractor registration
Department of Natural Resources	1111 Washington St SE PO Box 47000 Olympia, WA 98504-7000	(360) 902-1000 (Main) (360) 902 1450 (Geology and Earth Sciences) <http://www.dnr.wa.gov/pages/default.aspx>	Liquefaction susceptibility maps
State Building Code Council (SBCC)	906 Columbia St SW PO Box 48300 Olympia, WA 98504-8300	(360) 586-0486 <http://www.sbcc.wa.gov/>	-International Building Code -Uniform Plumbing Code -International Fire Code
Fire Protection Bureau (State Fire Marshal's Office)	PO Box 42600 Olympia, WA 98504-2600	(360) 753-0404 <http://www.wsp.wa.gov/fire/firemars.htm>	-Fire prevention information -Fire sprinkler information
Department of Transportation (DOT) Engineering Publications	PO Box 47400 Olympia, WA 98504-2600	(360) 705-7430 <http://www.wsdot.wa.gov/biz/construction/morebooks.cfm>	-Technical and construction manuals -Standard specifications
Utilities and Transportation Commission (UTC)	PO Box 47250 Olympia, WA 98504-7250	(360) 664-1160 <http://www.wutc.wa.gov/water>	Requirements related to inventory owned water systems (water companies)

Agency Name	Mailing Address	Telephone and Web Site	Information or Publications Available
Other Organizations			
American Water Works Association (AWWA) National Office	6666 West Quincy Avenue Denver, CO 80235	(303) 794-7711 <http://www.awwa.org/>	-Standards -Water Research Foundation reports -Manuals -Standard methods -Various journals and periodicals
Pacific Northwest Section – AWWA (PNWS-AWWA)	PO Box 80910 Portland, OR 97280	(503) 760-6460 <http://www.pnws-awwa.org/index.asp>	-Brochures Bill stuffers -Handouts on various subjects -Cross-Connection Control Manual
Health Education Services Division of HRI	PO Box 7126 Albany, NY 12224	(518) 439-7286 <http://www.hes.org/>	Ten States Standards
National Drought Mitigation Center	PO Box 830749 Lincoln, NE 68583-0749	(402) 472-6707 <http://drought.unl.edu/>	U.S. Drought Monitor
NSF International (formerly the National Sanitation Foundation)	PO Box 130140 Ann Arbor, MI 48113-0140	(734) 769-8010 <http://www.nsf.org/>	-List of NSF-approved products -NSF Standards
University of Southern California (USC) Foundation for Cross-Connection Control and Hydraulic Research	Kaprielian Hall 200 Los Angeles, CA 90089	(213) 740-2032 <http://www.usc.edu/dept/fccchr/>	-Approved Backflow Assemblies List -Manual of Cross-Connection Control

Agency Name	Mailing Address	Telephone and Web Site	Information or Publications Available
Washington Surveying and Rating Bureau	200 First Avenue, Suite 500 Seattle, WA 98119 4407 North Division Street, Suite 502 Spokane, WA 99207	(206)217-9772 (Seattle) (509) 487-3899 (Spokane) <http://www.wsrb.com/>	Insurance ratings
Western Regional Climate Center	Desert Research Institute 2215 Raggio Parkway Reno, NV 89512	(775) 674-7010 <http://www.wrcc.dri.edu/>	-Climate data -Rainfall data

Appendix D: Background and Development of Residential Water Demand vs. Precipitation

Appendix D is a study originally published in 1999.

Data Collection

A basic tenet for the revised design standards was to provide a conservative basis for designing new water system development, or extensions to existing development, whenever more reliable historical data was unavailable. It was recognized that a basic design parameter such as residential water demand may be better estimated if it could be based on available information throughout the state that could be both accessible and reliable. Information gained from water system records throughout the state, or from other locales with residential developments similar to this state, would be useful and generally more applicable to the establishment of a general design standard.

In attempts to secure accurate water use data from all parts of the state, three sources of information were used - two from surveys conducted by the department and one from reviews of documented information contained in various utility Water System Plans (WSPs) which had been submitted to, and approved by, the state DOH. An additional source of information was a report prepared by the California Department of Water Resources.

An initial (1993-94) survey questionnaire was sent to 30 selected utilities representing a uniform geographical distribution throughout the state. This survey was intended to determine a complete accounting of all water uses experienced by the utility from which specific data regarding residential uses could be derived. Questions were asked for number of metered accounts, total annual water demand, total population served, recorded average annual demands for all types of accounts (residential, industrial, commercial), multi-family uses (if possible to discern), recorded maximum day demands, and estimates of unaccounted water uses. The information was requested for the three year period, 1990-92. Also, the average annual rainfall for the utility service area was requested, if it were known by the utility. Where rainfall data was not provided by the responding systems, rainfall levels were determined from Meteorological Service records for the gauging station within, or nearest to, the utility.

For the 19 survey responses received from the initial questionnaire, the information was analyzed in an attempt to identify the water demands associated only with residential uses. This data was in turn correlated with rainfall records for the area. Of the survey responses returned, nine were of sufficient detail that residential demand estimates could be made with a relatively high degree of confidence. Information regarding maximum daily demands was generally not readily available, although in some instances water systems did present estimates of maximum day uses based on ratios to their peak monthly demands. The ratios of maximum day use to peak month use ranged from 1.4 to 2.7 for those utilities providing an estimate.

Because the results of the initial survey were insufficient to develop generalized relationships useful for design standards, a second survey was conducted in early 1995. Thirty-eight (geographically distributed statewide) water utilities were asked for more directed information.

Under the logical premise that irrigation demands were strongly associated with residential lot size, questions were asked regarding specific metered residential accounts in service locations where residential densities could be determined (i.e. utilities were asked to provide actual meter data from 20 to 30 accounts located in portions of their service area which ranged from a low density of one or less services per acre to a high density of five services per acre). The year for which utility meter records were to be reviewed and assessed was 1993.

Twenty-six systems responded to the survey and presented information based on actual 1993 meter readings for residential accounts, and where possible, an estimate of the residential density (ranges requested were for one or fewer units per acre, two units per acre, three units per acre, four units per acre, and in some cases, five units per acre) for those locations in their systems from which the meter records were taken.

The analysis of this information provided somewhat more direct, and presumably more accurate, estimates of annual residential water demands. Since 1993 was unusual in that the summer period experienced higher than normal rainfall, the demand data were related to the rainfall records for that year rather than using average annual rainfalls.

Analysis of the relationship of water demand to lot size, although generally showing that higher demands were related to larger lot sizes, and that this aspect was especially pronounced for lots in excess of an acre as compared to higher density developments (especially in eastern Washington), was not supported by sufficient unequivocal data to allow formulation of quantifiable design relationships.

However, the design engineer is to be cautioned that the size of residential lots, especially in eastern Washington, is clearly influential on the expected water demands, particularly for lots larger than an acre in size. As much as 60 percent more water may be used by a residence on an acre-plus lot than on lots which are less than an acre. The engineer must be cognizant of this aspect, and will generally be held accountable for proper consideration of this factor, when estimating water demands for tracts with large lot sizes.

Additional (and considered reliable), information on residential water demands was also found through reviews of 28 Water System Plans (WSPs) which had received DOH approval in 1995 to early 1996. The information from these WSPs was specific to residential water demands associated with meter readings or from professional engineer estimates. These data were then related to the rainfall records information documented in the WSP or from data on file with the Meteorological Service for gauging locations proximal to the utility.

Additional information was also collected from a 1994 report prepared by the California Department of Water Resources (Bulletin 166-4, "Urban Water Use in CA," August 1994). Included in this report (which provided a wide array of recorded water use patterns specific to utilities or geographic areas in California) was some summary data for twenty selected utilities which associated a ten-year average annual demand (on a per capita basis) to average annual rainfall. Using a factor of 2.7 persons per Equivalent Residential Unit, estimates of the average annual demands for 19 of these utilities (in terms of gallons per day per ERU) were made and incorporated into the data set used for this demand analysis. (One utility, Palm Springs, had demands that were influenced so greatly by an abnormally large transient population that it could not be considered reflective of a true residential community, and was therefore not included in the data set).

Data Analysis

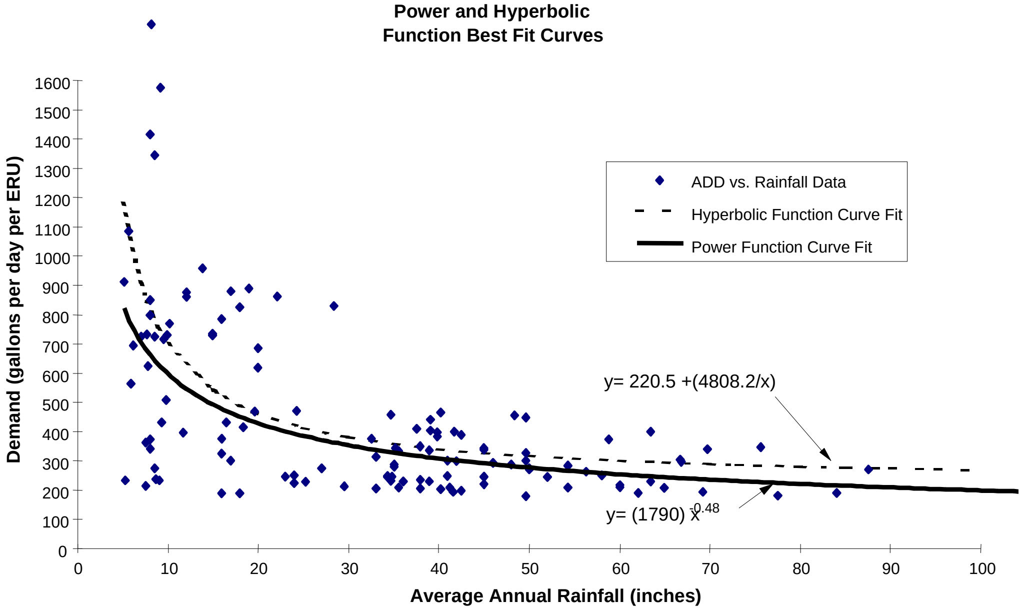
The data (a total of 122 data points) were evaluated in an attempt to identify and characterize any discernable relationships. Although it was recognized that many factors exist which could influence residential water demands, with the exception of average annual rainfall there appeared to be insufficient information to draw relationships with any other factor which could be used as a numerical and rational basis for specifying design parameters. In earlier drafts of the revised design standards, factors were developed and proposed to account for water demand influences associated with residential density. From the data available there was clear evidence that lot size was related to water use in both Western and Eastern Washington. However, the data were limited and could not be reasonably applied to specific relationships descriptive of statewide observations. The impact of lot size was, therefore, not accounted by some design relationship, but was addressed as a qualitative aspect of design, which must be considered and addressed. For other factors (such as economic status, pricing structure, landscaping practices, conservation practices, etc.) which can be of significant influence on water demand, there was insufficient information to draw any relationships or qualitative conclusions. Some water systems may have in the past developed specific relationships between several of these factors and their water demands, but such relationships would be specific to an individual system and would not be applicable on a statewide basis, unless they could be verified through collection and analysis of additional and reliable information.

Development of Rainfall/Residential Demand Relationship

The data were plotted in an x-y scatter plot and visually inspected. From an examination of the plotted data, there seemed to be a generalized relationship between average annual demand for residential developments and average annual rainfall. It was apparent that use of a single value for demand estimates on a per household basis (as has been historically the practice), for the design of residential water systems was not particularly appropriate. A curvilinear function appeared to be more descriptive of average water demands when associated with such a climatic factor as average annual rainfall.

Accepting that the data could be better described by a curvilinear function, several different fitting models were used to develop best-fit curves for the data. Figure D-1 presents two best-fit curves, one based on a hyperbolic function, and a second based on a power function. Both provide similar fits to the data set, with correlation coefficients (R) of 0.49 and 0.61, respectively. Although these correlations are not as strong as one would like to develop basic relational equations, they were considered sufficient to allow acceptance of the general form of a function which could be used for water demand design criteria. The data scatter in the low rainfall areas contribute significantly to the marginal correlations with rainfall which points out the influence of other factors in determining average daily demands for residential populations.

Figure D-1
Power and Hyperbolic
Function Best Fit Curves



In order to determine confidence intervals (C.I.s) for the mean of the data set, and more usefully in this application, prediction intervals for individual points, the data were transformed to develop a linear relationship. A log x-log y transformation provided a data set with a linear regression line corresponding to the best-fit power function curve. The linear regression line for the plot of y vs. 1/x corresponds to the hyperbolic function. The transformed data and appropriate C.I.s are presented in Figures D-2 and D-3, and were developed using SPSS statistical software.

Mean and Point Prediction Intervals at 60%

The centerline in Figures D-2 and D-3 represent the mean of the data set. The curved lines on each side of the center line are the 60 percent confidence bounds for the mean of the data, and the parallel lines at the outer portions of the data are the 60 percent Prediction Intervals for individual points. That is, based on the data available, and standard assumptions about the validity of that data as representative of the larger population, it can be said with 60 percent certainty that usage, as a function of rainfall, of any new data point will fall between the two outer, parallel lines. It is noted that although 60 percent represents a relatively marginal level of confidence, the notable data scatter in the low rainfall range biases these results.

Figure D-2: Log Transformation of Average Day Demand vs. Rainfall (Power Function)

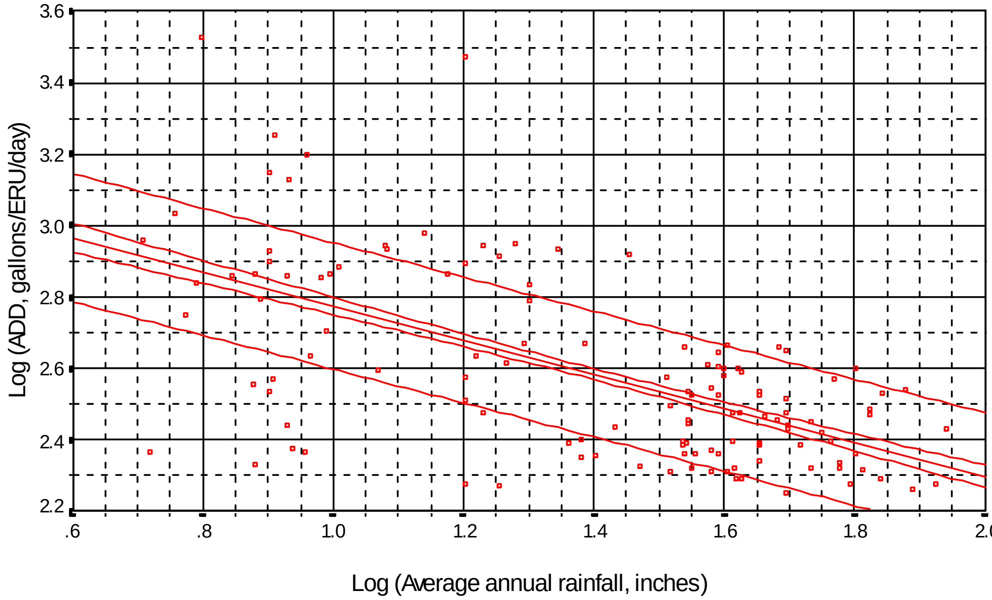
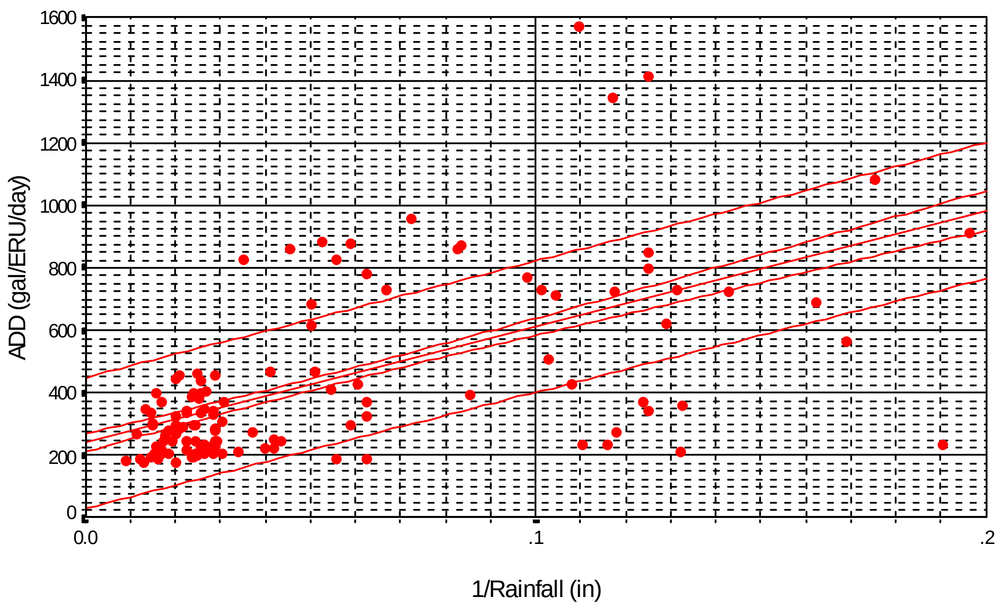


Figure D-3: Transformation of Average Day Demand vs. Reciprocal of Rainfall (Hyperbolic Function)



An upper level curve for the Power Function based on the 60% confidence boundary, when plotted back to arithmetic coordinates, indicates that 85% of all points are below the upper bound. For rainfalls averaging less than 30 inches per year, almost all points are below the upper bound.

Review of Figures D-2 and D-3 indicates that transforming the data based on a hyperbolic function (i.e. y vs. 1/x) provides a slightly poorer linear relationship than the power function. However, the difference was not considered of such significance that use of a hyperbolic relationship could be discounted.

Baseline Residential Water Demand

The data (shown in Figure D-1) shows an interesting aspect which appears to have general application and credence for baseline residential water demands. With only a few exceptions where a few data points can be seen to be lower, all data generally lied above a value of 200 gpd/ERU (i.e., at all rainfall levels, the average annual demands reported were greater than 200 gpd/ERU). This observation may be construed as a threshold level for residential demands which appear to be independent of average annual precipitation levels and may indicate the base level of demand associated with internal household (non-irrigation, etc.) uses. As such, the function which describes the relationship between ADD and average annual rainfall would be more strongly associated with external household uses (irrigation, lawn watering, etc.). Assuming this is the case, design requirements for total demands could be separated into two components - one related to internal uses and the other to external uses. For internal demands, a constant value independent of rainfall could be prescribed and for external demands, a relational function could be established which was dependent upon rainfall levels.

From the data, the single valued level for average annual household demands (internal uses), which would appear to apply statewide independent of rainfall, is about 200 gpd/ERU. Logic dictates that this demand may be consistent on an average annual basis, but cannot be expected to be uniform on a day to day basis. Residential households would be expected to experience peak demand days for internal uses associated with a number of factors. Peak day uses could be expected with increased water demands for showering in the summer, or when visitors or relatives are entertained. The actual levels associated with the peaking demand days would be dependent upon many variables. There were no known relational studies, or anecdotal accounts, that could be found which would assist in development of design parameters for internal household peaking uses. Nonetheless, in order to maintain consistency with stipulations of the state's Group B water system design criteria, and with the Department of Ecology, who in some instances provides estimates of peak day internal uses for water rights issues, a reasonable level for a Maximum Daily Residential Demand for internal uses can be established at 350 gpd/ERU (a value which can be seen is marginally less than double the average annual internal demand of 200 gpd/ERU previously discussed).

For projects that propose to have separate irrigation systems, the design of the potable (internal use) water system can be predicated on the estimate of 350 gpd/ERU. The irrigation portion of the system may be designed based on the respective needs of the customers, or by using the difference between the demand estimated for complete service (Maximum Total Daily Demand) and that for just the internal uses (Maximum Internal Daily Demand).

Selection of Design Functions for Residential Water Demands

In development of a functional design relationship which can be used for estimating the residential water demands in Washington State a number of approaches were examined:

- Based on the statistical features of the data set, a function that described the relationship associated with the upper bound of the 60% confidence interval could be used.
- The current approach that sets demand levels at constant values for Eastern and Western Washington could be retained. However, this "status quo" approach may not be particularly applicable based on a review of the data. There appears to be a trend better described by a continuous function rather than by a single, but separate, value ascribed to water system design simply because of gross climatic differences between East and West Washington.
- Another approach would be to establish a function that gives criteria higher than any recorded data to insure that, at least, the data set available was completely accounted in a highly conservative manner.

The foregoing approaches were all rejected under criteria that were believed appropriate to guide the design function selection process. It was considered reasonable and prudent to establish an approach that would provide for a relationship that was patterned to the "best-fit" curves developed for the data that were sufficiently conservative so that reasonable confidence could be placed on the use of the design relationship (i.e., the function would describe demands that were in excess of at least 80% of the recorded data), that the relationship would be as simple as possible to use and understand, and that the relationship would be asymptotic to a baseline demand of 200 gpd/ERU.

In addition, based on the wide range of reported data in the low rainfall range which showed some, but very few, systems that experienced very high average annual demands (> 1000 gpd/ERU), it was determined appropriate to establish an upper boundary of 1,000 gpd/ERU for any relationship (function) that was developed.

Under these criteria, two functions were developed, one a power function and the other a hyperbolic function, which were asymptotic to the 200 gpd/ERU lower boundary and which were presented in very simplistic terms. Another function was also developed, which does not show an asymptotic boundary associated with the 200-gpd/ERU level, but does parallel the best-fit power function relationship used for the previous data analysis. Each of these functions is conservative in that 80% or more of the data would lie below the curves describing the functions. Presented in Figure D-4 are three graphical relationships with their associative functions. One hyperbolic relationship and two power function relationships are presented, any of which may be used to estimate residential water demands throughout the state when no other better information is available or applied for design.

Although the power function relationship may have somewhat greater statistical strength, the relatively high conservative nature of these functions would allow for any of them to be used for design purposes. Since the hyperbolic function provides more conservative estimates at lower rainfall ranges, and is possibly the simplest to use and understand because of its arithmetic nature, it was selected as the function of choice for estimates of average annual residential demands used for project designs **when more appropriate information is not available.**

Maximum Day Demand

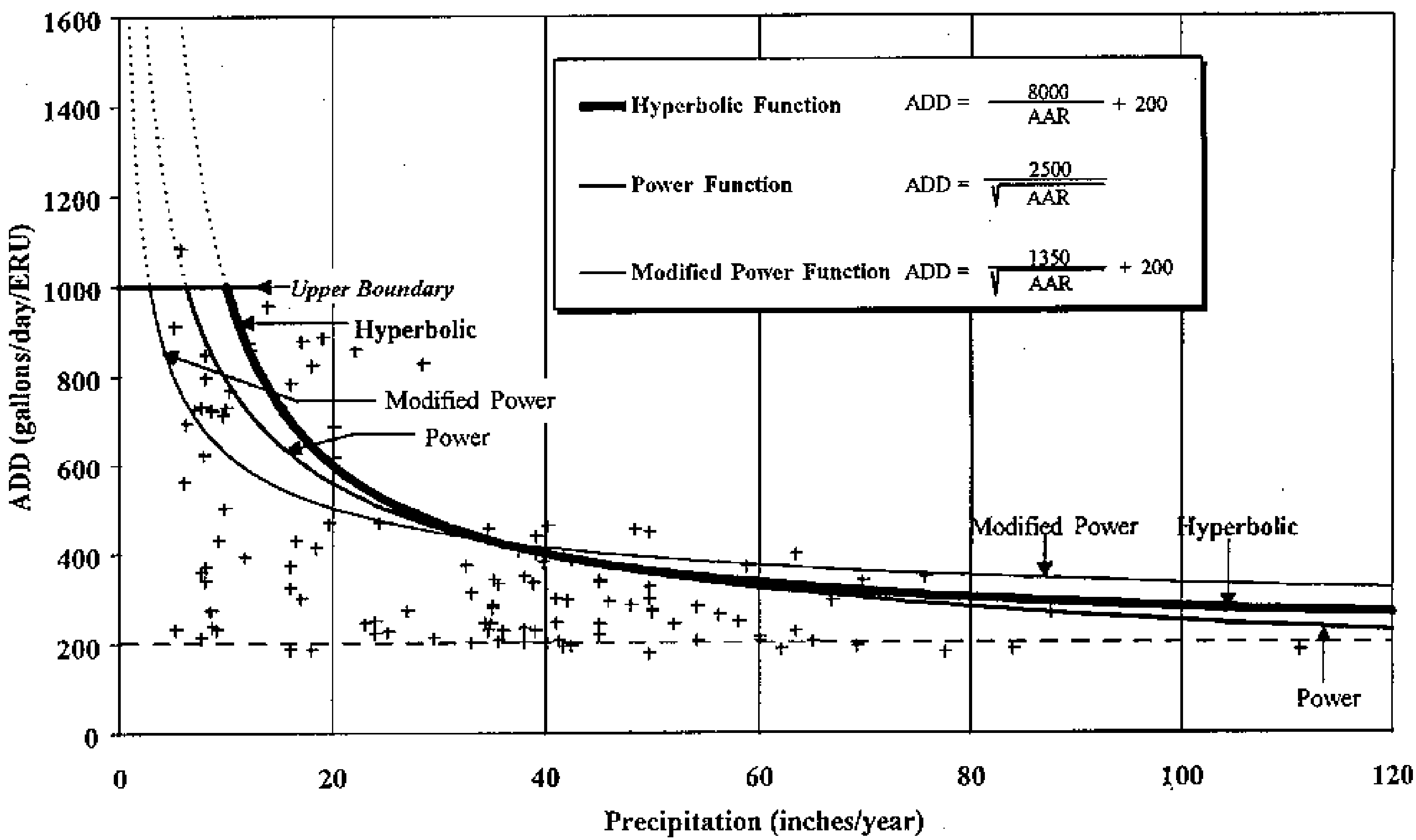
A variety of peaking factors have been reported in the literature and within the data collected for this analysis, but generally the Maximum Daily Demand (MDD) is 1.5 to 3 times average daily demand. By selecting an appropriately conservative approach to estimating ADDs (as was done in this analysis), use of a standard peaking factor of 2.0 was considered to be adequately conservative. MDD can therefore be calculated by multiplying ADD values by a factor of 2.0. Again, an upper maximum level would be been established based on the upper boundary for the average annual demand (1000 gpd/ERU). The MDD value would be 2000 gal/day/ERU as an upper bound. The absolute lower limit MDD values, as previously discussed, are set at 350 gpd/ERU (for developments without irrigation or with restrictions on the external use of water).

Limitations of This Analysis

It is clear from inspection of the graphs presented in this appendix that the data varies widely, and the existence of many other factors that affect both average annual and peak daily water use have been acknowledged. **The intent of this document is to ensure that new systems, or system improvements, are designed based on reasonable and conservative criteria when there is an absence of sufficient production and use data to allow other design parameters to be used.** The approaches presented here reflect this philosophy, and as such, have tried to use relatively sparse data in a reasonable and judicious manner. The water demand design criteria contained in the Design Manual (Chapter 5) represent an improvement over what has historically been used in the state. In the future as more and better information becomes available, even greater refinement of the approaches can be expected.

FIGURE D-4

Functional Relationships Describing Average Residential Demand Relative to Average Annual Rainfall Levels



Appendix E: Recommended Pumping Test Procedures

1.0 Introduction

This aquifer pumping test procedures document specifies the minimum pumping test procedures that DOH considers sufficient for demonstrating that a new source is capable of providing a safe and reliable yield of water for the water system. This pumping test procedures document was prepared to provide Group A water systems with basic information suitable to develop an approach to satisfy the source approval requirements in WAC 246-290-130 (3)(c)(iii) and (3)(d). Information is presented to enable a water system to address DOH concerns regarding the most commonly encountered aquifer conditions or hydrogeologic settings across the state. Situations involving complex hydrogeolgic settings, however, may require a high level of expertise and experience to adequately design and evaluate pumping tests for demonstrating source reliability. Stand-alone pumping test procedures specifying the minimum steps DOH consider adequate are presented at the end of this document. A discussion of the basic components of a pumping test is also provided to assist with understanding the procedures presented in this document. The intent of this document, however, is not to provide a detailed step-by-step approach for conducting or analyzing a pumping test. Numerous references provide detailed, industry-accepted information on designing the specifics of a pumping or aquifer test. A list of selected references is provided at the end of Section 5.0 of this document.

The principal objective of the pumping test is to obtain adequate information for DOH to evaluate whether a source is capable of reliably providing a safe yield of groundwater. This objective differs somewhat from the Department of Ecology's whose concern is focused on overall protection of the aquifer. In establishing water rights, the Department of Ecology evaluates withdrawals from all users and recharge to the aquifer, and considers future water needs from the aquifer.

This procedures document is not intended to evaluate the aquifer as a water resource, but rather to establish the ability of the source to meet the design pumping rate. Reliability considers the ability of the source over time to meet normal conditions of operation, without adversely affecting the water quality or quantity demands of the water system. The reliability of groundwater yield requires that the pumping test results can be projected for some time into the future. From DOH's perspective, a properly conducted pumping test is the best basis from which to judge a source's current and future reliability. A pumping test can indicate lateral flow boundaries, hydraulic continuity, constraints of fracture flow, and recharge. All of these can be important factors in establishing reliability. From the water system's perspective, the pumping test is the best method by which to size and establish the optimal depth setting of the pump, as well as, establish water system storage and operational needs. Proper pump sizing and depth selection can provide considerable savings to a water system over the lifetime of the well, through reduced power consumption and maintenance costs.

WAC 246-290-130(c)(iii) states that one acceptable approach for demonstrating source reliability is to conduct a pumping test at the maximum design rate and duration. For DOH to make a source reliability assessment, Section 7.3 and Appendix F specify the pumping test and hydraulic parameter information that should be submitted to DOH in a project report.

Those information requests pertaining to the pumping test portion of the report are summarized below:

- Measurements of the static water level prior to pumping (in the test well and observation wells, if any);
- All water level data for both the pumping and recovery phases of the pumping test;
- Graphical presentations of the data, as appropriate;
- Transmissivity, saturated thickness, and hydraulic conductivity values/calculations for the producing aquifer;
- Storage coefficient and specific yield for the producing aquifer;
- Delineation of the 6-month, 1-, 5-, and 10-year time-of-travel zones for each well;
- Identification of any hydraulic connection with surface water; and
- Conveyance of pumped water.

This document is divided into three main sections.

1. Section 2.0 discusses the rationale of DOH basic pumping test procedures, and the general approach for a water system to use when determining a pumping test protocol for obtaining DOH new source approval. This is followed by a discussion of special aquifer settings DOH has identified as having greater potential for concern regarding water quality and the ability of the aquifer to provide a reliable source of water. Section 3.0 also describes the basic pumping test requirements, provides the rationale behind their selection, and presents a flow chart for a water system to follow for selecting a pumping test.
2. Section 4.0 discusses what to do if the test is improperly conducted or goes wrong, and at what point the test would probably not produce adequate data for DOH to conduct a source reliability evaluation.
3. Section 5.0 discusses pumping test components and defines terms used throughout this document.

The stand-alone pumping test procedures for each of the basic pumping tests are provided at the end of this document. These procedures summarize the basic instructions for the step drawdown and constant rate discharge-pumping test, including specific instructions for sources with concern for saltwater intrusion.

2.0 Basic Pumping Test Approach

Various aquifer settings can be encountered when evaluating source reliability. For most settings, source reliability will be defined sufficiently by conducting one or two basic pumping tests. If necessary, adjustments can be made to the basic pumping test to address aquifer settings needing more rigorous data collection and analysis.

Under WAC 246-290-130(c)(iii), DOH requires that a minimum of two components be addressed when determining whether the source will be able to produce a reliable groundwater yield. The first component is to determine the pump size and depth setting appropriate for the aquifer and well. In most cases, this will require that a step drawdown test be conducted. The second component is to determine whether this pumping rate can be maintained for some time into the future. This test of reliability is accomplished by conducting a constant rate discharge test. Under certain conditions, a single test—either a step drawdown or constant rate test—may be adequate.

What is a step drawdown test? The step drawdown test is similar to the constant-rate discharge test in many respects. The major difference being that the step drawdown test consists of several short-duration, constant-rate discharge tests—each run at a progressively higher pumping rate. The minimum suggested *step drawdown* test consists of at least four different pumping rates, each conducted for a minimum duration of 60 minutes. It is important, however, to run the initial step long enough to establish that the effects of well storage have dissipated. The remaining steps should each be run for the same duration as the initial step.

This step drawdown test provides a range of specific capacities for the well and is therefore, the most reliable method for determining the pump size and setting. This test produces minimal aquifer information, however, and will likely not identify impermeable boundaries, recharge boundaries, interferences from other wells, or conditions of groundwater under the influence of surface water, unless these conditions exist in very close proximity to the well being tested.

In most cases, a step drawdown test would be recommended to establish the optimal pumping rate and depth for water system operation and to determine the pumping rate at which the constant rate discharge test should be conducted. As mentioned, the step drawdown test produces minimal information regarding aquifer characteristics and generally does not involve observation wells. Therefore, where information on long-term productivity is critical or lacking, a constant rate discharge test is needed.

The following paragraphs provide the basic pumping test recommendations for water systems seeking new source approval or water system expansion where an existing source is utilized. Information is also provided about DOH approaches and concerns to be addressed when the aquifer response to pumping is anticipated to differ from a “standard” setting. “Standard” applies to a wide range of conditions that could be encountered in source development. For the pumping test requirements, a standard setting is defined as one in which water quality and water reliability concerns are expected to be minimal. Within the standard setting, the results of the pumping test could indicate the presence of flow boundaries (impermeable or recharge) and that the source is in direct hydraulic connection with surface water. Encountering these conditions during a pumping test does not necessarily indicate that there are concerns from a water quality or a source reliability standpoint.

Table 1 in this Appendix has the hydraulic parameters that can be determined directly from the pumping tests or a pumping test measurement component. Some parameters may be determined in more than one manner. To determine all of the requested reporting information, however, it is necessary to collect data during all aspects of a pumping test.

A pumping test is likely necessary under either of the following situations: 1) new source approval or expansion of an existing water system, and 2) source capacity may be in question (WAC 246-290-130(c)(iii)). Table 2 presents the pumping test recommendations for the aquifer settings most likely to be encountered during development of a new source. In most cases, an initial step drawdown test is recommended. There is only one condition where the step drawdown test is not believed advisable. This condition occurs in standard aquifer settings where adequate hydrogeological information exists to establish a sustainable pumping rate. This situation could include a new source that will be used in a multiple well, paired well, or tandem well configuration.

Figure 1 is a flow chart, which can be used to establish the appropriate pumping test, and to identify those concerns to be addressed in a report sent to DOH. As an initial step, a water system would be expected to review any existing hydrogeologic information to assist in identifying any concerns which careful pumping test design could address. In many situations, including standard aquifer settings and any areas of existing water quality or quantity concerns, a water system would be expected to conduct *at a minimum*, a four-point step drawdown test. This would be followed by a minimum, 24-hour constant rate discharge test with a minimum of 4 hours of stabilized drawdown data and completed with the collection of recovery data. The constant rate discharge test would be conducted at the pump settings determined from the step drawdown test and after aquifer recovery from the test. As a general rule, the aquifer should be allowed to recover to within 95 percent of the static water level as measured prior to conducting the step drawdown test. In situations common to small water systems, where a low demand source is completed in a high productivity aquifer, it is expected that running the final step of the step drawdown test until 4 hours of stabilized drawdown data have been collected will be sufficient to establish source reliability. An example of this situation is a small water system with a source completed in a high flow aquifer where drawdown stabilization would be expected to occur quite rapidly.

Table 1: Data Provided by Pumping Test and Drawdown Measurements

Step Drawdown Test	Constant Rate Test	Recovery Data	Observation Wells Data
Well Efficiency, Pumping Rate (Q), Transmissivity (T), Specific Capacity (sc), Yield	T, sc, Hydraulic Conductivity (K), Yield	T, S	S

Definitions	Comments
Pumping Rate (Q) = gallons per minute [gpm]	None
Yield = volume/time [gpm]	None
Specific Capacity (sc) = yield/drawdown [gpm/ft]	Allows well yields to be calculated at various drawdown levels. This information is needed to determine the maximum yield of the well and can be used to examine the economics of well operation at a given yield.
Transmissivity (T) = K*b [gpd/ft], (K = hydraulic conductivity [gal/day/ft^2] and b = aquifer thickness [ft])	Transmissivity can also be calculated from the pumping test graphical solution using either the Nonequilibrium Well Equation or the Modified Nonequilibrium Equation. This value provides a measure of how much water will move through the aquifer as defined by a 1-ft wide vertical strip extending through the full, saturated thickness of the aquifer, under a hydraulic gradient of 1.
Coefficient of Storage (S) = [dimensionless], can be calculated directly from the pumping test graphical solution using either the Nonequilibrium Well Equation or the Modified Nonequilibrium Equation	This provides a measure of how much water can be pumped or drained from the aquifer per unit of aquifer storage area per unit change in head. This value can only be calculated if observation wells are incorporated into the pumping test. *If no observation wells;* for a confined aquifer, a value of $sc = 5 \times 10^{-4}$ may be used; for an unconfined aquifer, a value of $sc = 0.1$ may be assumed for calculations of well performance and interference between wells.
Well Efficiency = theoretical drawdown/actual drawdown [dimensionless], expressed as a percent	Highly inefficient wells may or may not be something that can be addressed. This information can be very valuable if additional wells are planned or can indicate that the well would benefit from further or re-development.

Table 2: Aquifer Settings and Appropriate Tests

Setting Description	Step Drawdown Test	Constant Rate Test	Recovery Data	Observation Wells
Standard Aquifer Setting				
No Expected Problems Or Concerns With Aquifer Productivity	Yes[1] (recommended)	Yes (optional)	Yes (recommended)	Should be used if available
Special Aquifer Settings (at Q established by step drawdown test)				
Low Flow Conditions	Yes	Yes	Yes	No
Fracture Flow	Yes	Yes	Yes	Should be used if available
Aquifer Of Limited Areal Extent	Yes	Yes	Yes	Should be used if available
Saltwater Intrusion Potential	Yes	Yes	Yes	Should be used if available
Multiple Wells/Tandem Wells	Not Necessary	New well only	Yes	Yes

[1] In settings of a high productivity aquifer, low demand source, and no water quality issues; to demonstrate source reliability, the final step should be run until four hours of stabilized drawdown data have been collected and well recovery should be measured. Under these circumstances only, a constant rate test is unnecessary.

How to set pumping rate (Q) for ***step drawdown*** *discharge test*:

1. Set Q as follows:
   Use the maximum design pumping rate as Q for the 3rd step. Multiply this value by 0.5, 0.75, and 1.25 to obtain Q for the 1st, 2nd and 4th steps, respectively.

How to set pumping rate (Q) for ***constant rate*** *discharge test*:

<u>Method (in order of preference)</u>

1. Conduct step drawdown test to establish optimal Q, or if step drawdown test is **not necessary**

a. use maximum design pumping rate.

b. check with other aquifer test results conducted in the area.

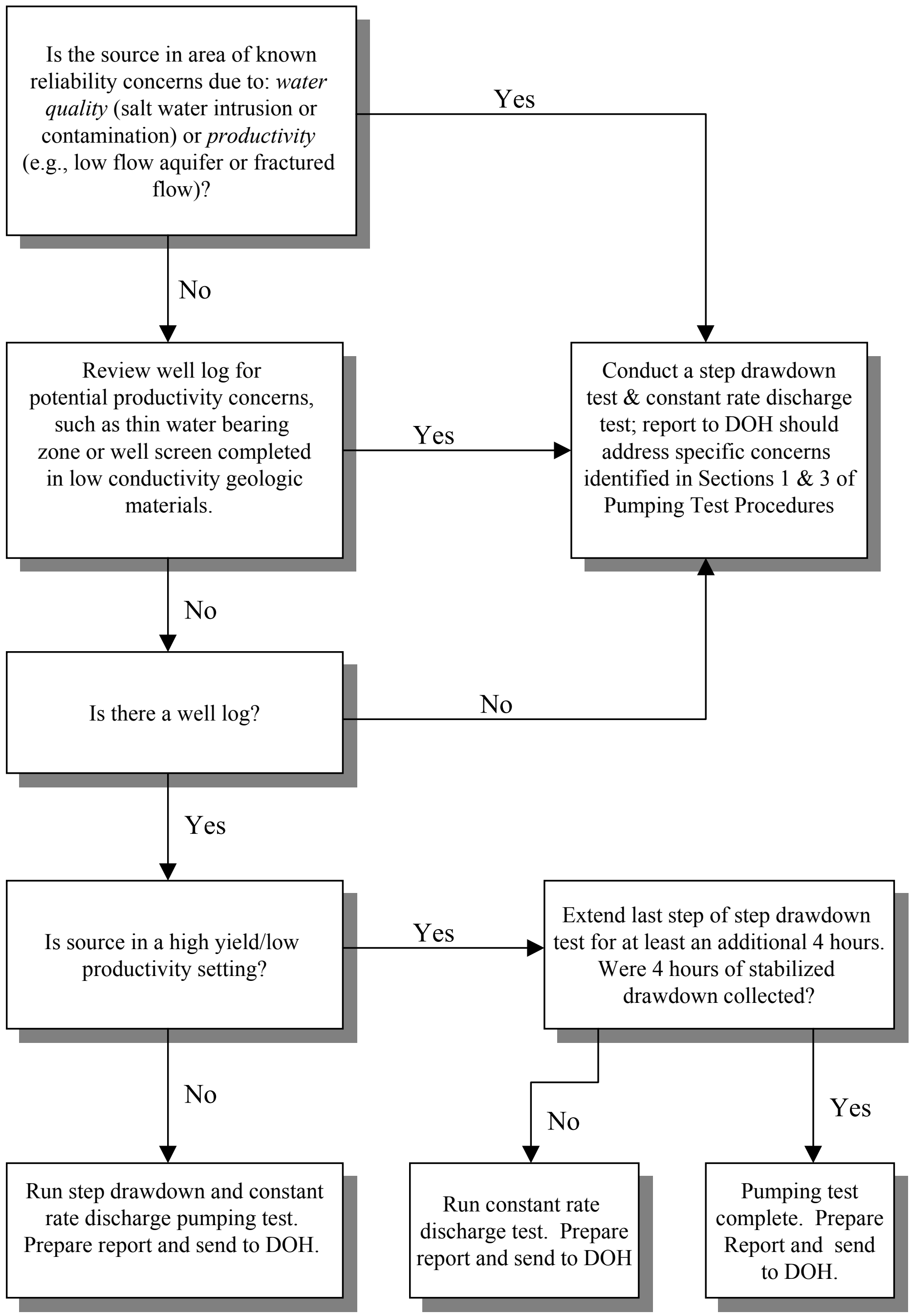


Figure 1

PUMPING TEST
PROCESS FLOW CHART

3.0 Pumping Test Concerns in Special Aquifer Settings

Several aquifer settings have been identified as having a greater potential for reliability concerns and were presented on Table 2. Reliability concerns include both water quality concerns (such as high chloride levels or other contaminants) and water quantity concerns (such as seasonal availability or aquifer continuity). Typically, these aquifer settings do not require that different types of pumping tests be conducted. However, they may require a longer test or more rigorous analysis of certain aspects of the pumping test results. Because of the greater difficulty and complexity in pumping test design and evaluation presented by these settings, consultation with an experienced hydrogeologist or engineer may be advisable. DOH information elements and concerns unique to these conditions are discussed below.

Low Flow Conditions

Low flow conditions could be encountered for wells completed in materials of low hydraulic conductivity such as silts, sandy clays or sandy silts, weathered sandstone, and other weathered consolidated materials. In these cases, the ability of the well and aquifer to produce at the required pumping rate is of concern, not necessarily the quantity of water available. Turbulent flow induced during pumping can result in a significant decrease in aquifer performance with increasing pumping rate. Therefore, a step drawdown test is recommended to determine the specific capacity, yield, and the optimal pump settings.

Because it is unlikely that boundary conditions would be encountered in low-flow conditions during the step drawdown test, a constant rate discharge test is also recommended. The maximum pump setting, as determined from the step drawdown test, should be used for the constant rate discharge test. The constant rate discharge test should be run after the static water level has stabilized at initial levels (following the step drawdown test recovery period). DOH is interested in an evaluation of aquifer stabilization and constant-rate discharge test drawdown effects to demonstrate longer-term reliability of the source. Observation wells are not necessary, even if available, because effects of pumping in low-flow conditions are typically not far reaching.

Fracture Flow

DOH concern for fractured material is based on whether the source is adequately evaluated to demonstrate that pumping requirements can be met over the long term. Typically, sources completed in bedrock composed of shale, basalt, granite or any consolidated material can have fractured flow concerns. The continuity of fractures can vary significantly within an aquifer and affect its ability to provide water in a consistent manner. This difficulty may be compounded by a lack of seasonal source reliability. Recharge may vary seasonally and cause production problems in low flow periods (low water level and low recharge). During these periods excessive drawdown may occur. Because of these concerns, each source must demonstrate an ability to provide a safe and reliable yield.

The reliability of an individual source in the aquifer does not define the reliability of other sources in this type of setting. A step drawdown test is recommended to determine the optimal pump setting for consistent yield. A constant rate discharge test is also recommended to demonstrate long-term reliability. The constant rate discharge test should be conducted at the optimal pumping rate and pump depth setting indicated by the step drawdown test results.

Restrictive conditions identified by the pumping test could include lack of stabilization, for example, drawdown continues to increase with time. This could signify that recharge does not occur within the aquifer at a rate sufficient to maintain consistent discharge at the desired pumping rate. It is also possible that the rate of drawdown decreases with time. This effect would suggest that a recharge boundary was encountered and that the source could be capable of producing a reliable yield. Observation wells should be used if available, because measurement of drawdown in these wells can provide an indication of the extensiveness and interconnectivity of the fractures. Selection of appropriate observation wells in a fractured setting, however, can be problematic and may warrant input from a hydrogeologist or engineer experienced in pumping test design.

Aquifer of Limited Areal Extent

This aquifer condition presents the same type of concerns as fracture flow. Although wells in this setting may initially be able to provide a reliable source of water, because of limited areal extent and recharge capacity, these aquifers may be unable to produce over the long term at the desired pumping rate. These aquifers are commonly made up of highly variable material, which may also show significant variation in its ability to transmit water. For this reason, a step drawdown test is recommended to determine the pump depth and settings. Again, because of the often variable nature of the geologic materials throughout the water-bearing zone, a constant rate discharge test is recommended to identify any recharge boundaries or impermeable boundaries. The characteristics of the data and their significance are similar to those presented above in the discussion for fractured flow. If available, observation wells should be used so that the coefficient of storage can be determined as accurately as possible.

Saltwater Intrusion

In addition to demonstrating that the well and aquifer are capable of producing a reliable yield of groundwater, an assessment of the potential for inducing saltwater intrusion in the pumping well or nearby wells is also requested. The pumping test recommendations are identical to those previously discussed in the special aquifer settings. Initially, the pump settings are determined by the results of a step drawdown test, which is followed with a constant rate discharge test to assess the longer-term reliability of the aquifer. Ideally, observation wells should be selected so that they are positioned between the pumping well and the saltwater body. In situations where observation wells are present but in less desirable locations, it is still recommended that those wells be used to allow calculation of storage coefficient and other hydraulic parameters data. In areas where the potential for saltwater intrusion is high, it is also important to evaluate tidal influences prior to conducting the pumping test. This is also a situation where because of the complexity of pumping test design and evaluation, input from an experienced hydrogeologist or engineer may be beneficial.

Pumping tests in potential saltwater intrusion areas differ from the other aquifer settings primarily in that, water quality tests for chloride and specific conductance are needed in both the pumped wells and observation wells at specific intervals throughout the aquifer test period. These water quality indicators are monitored in the field using instruments specific to these parameters. Water quality measurements are to be made to determine whether concentrations are increasing, potentially signifying that saltwater is being drawn towards the pumping well. Stabilization in drawdown or the presence of a recharge boundary without an associated increase in chloride levels in the pumping well or observation wells would be favorable in demonstrating source reliability.

Multiple Wells/Tandem Wells

This setting refers to two or more wells completed in the same aquifer that will be pumped either cyclically or concurrently. DOH's primary concern in this setting is whether the new well interferes with other wells pumped by the water system or with aquifer recovery. Because of the variety of water system needs addressed by adding an additional well(s), it is recommended that the purveyor contact DOH to discuss a pumping test approach prior to actually conducting the test. This is also a situation where because of the complexity of pumping test design and evaluation, input from an experienced hydrogeologist or engineer may be beneficial.

In situations where a pumping test has been conducted for an existing well and data was also collected from an observation well(s), the potential for well interference due to adding an additional well can be determined using a distance-drawdown graph and evaluating additive drawdown for all pumping wells. In many instances, conducting an additional pumping test exclusively on the new well would provide little new information beyond validating the findings of the initial pumping test, unless it was conducted at the total concurrent pumping rate. In general, an evaluation of potential well interference for either cyclical or concurrent pumping can be determined using this approach. If an observation well was not used during the pumping test the same approach can be used, however, the results will likely be less accurate in predicting well interference.

Depending upon the new maximum design pumping rate and desired yield, however, this approach alone can fall short in demonstrating the ability of the aquifer to recover under the new pumping configuration. Therefore, in settings where the new maximum design pumping rate would significantly increase the required aquifer yield, DOH may request that a constant rate pumping test be conducted using the proposed maximum design pumping rate for all wells that would be concurrently pumped. For this reason, DOH considers each source approval in a multiple well/tandem well setting to be a unique situation and DOH should be consulted during the pumping test development process.

4.0 When Problems With Pumping Tests Occur

Tables 3 and 4 provide information regarding some of the more typical problems that can occur when conducting the step drawdown and constant rate discharge pumping test, respectively. The significance of these problems varies according to how far into the test they occur and to what degree they are caused by the aquifer responding to the pumping test or are due to human error.

These potential problems are discussed in terms of, at what point would DOH question the ability of the pumping test to demonstrate source reliability. This will vary, however, depending on how much information has been obtained from the pumping test and what the information provides towards establishing source reliability. As indicated in the tables, not all problems or situations would result in a recommendation that the pumping test be repeated.

5.0 Pumping Test Components

The following components require consideration when designing a pumping test. The information presented is not intended to be a resource on all aspects of pumping tests, but rather to provide an idea of the considerations necessary to plan a pumping test and to supplement the information presented in the individual policies presented later in this procedures document.

Duration

The duration of the pumping test is specified within each of the individual pumping test methodologies provided later in this appendix. It is *very important*, regardless of whether the pumping test conducted is constant-rate or step-drawdown, that the pumping rate is held as constant as possible during each phase of a pumping test. The step-drawdown procedure should be a minimum of four, 60-minute constant rate tests, with each run using an increasingly higher flow rate. It is important to run the initial step, however, for a duration long enough to demonstrate that well storage effects have dissipated. Each of the remaining three steps should be run for a length of time identical to the initial step. The pumping test duration for the constant rate discharge test is a minimum of 24 hours.

Pumping Rate

Fluctuations in pumping rate make the test analysis very difficult and raise questions as to whether deviations in the data are actually a result of flow boundaries or other hydrogeologic features. Control of the pumping rate is often best accomplished by accurately measuring and controlling the discharge rate. Consideration should be given to the type of pump used to conduct the test. A pump driven by a gasoline engine which needs to run at full throttle in order to meet the required pumping rate, may vary significantly in pumping rate. Using a pump with a large enough capacity to meet the required pumping rate at ½ to K full throttle will produce a more constant yield. Electric pumps are generally not subject to the same rate fluctuations as gasoline powered pumps. A valve in the discharge line, ½ to ¾ open, allows for flexibility in adjusting discharge rate if necessary. The pumping rate should be monitored every 10 to 15 minutes during the first hour of pumping and throughout each phase of the step drawdown test. At later times, the pumping rate should be monitored every 2-hours and the rate maintained within 10 percent of its starting value.

Table 3: Step Drawdown Test Problems and Their Significance to Demonstrating Source Reliability

Problem	Significance	Would Repeating Pumping Test Be Advised?
Discharge rate varies during pumping by more than 10%.	Stabilize discharge rate as quickly as possible. Discharge rate fluctuations make identification of optimal yield difficult.	Probably not, if it was only one of the steps and the follow-up constant rate discharge test was conducted adequately. Collection of recovery data would also provide adequate data.
Data collection does not occur at the minimum specified intervals.	Without data collection at a sufficient frequency, it is very difficult to establish what conditions may be affecting groundwater flow.	Yes
Well is pumped dry because pump was placed too close to static water level.	For the pumping tests, the pump should be placed as far below the static water level as possible without placing it within the screened interval of the well. This allows the maximum possible drawdown and maintains some degree of well efficiency.	Yes.
Well is pumped dry because the pumping rate is unsustainable.	No additional higher rate steps are necessary and the step drawdown test is complete at this point.	Repeating the test at the same pumping rate(s) would probably be of little value. Repeating the test at a lower rate would be advisable, if lower pumping rate drawdown data was not obtained.
Drawdown does not stabilize and shows continued increase.	This is likely to be the case for the step drawdown tests. The tests are short enough that drawdown is unlikely to stabilize, unless low demand source in a highly productive aquifer.	No, the test would not need to be repeated. If a water system extended the final step and did not achieve 4 hours of stabilization, then a constant rate discharge test should be conducted.
Drawdown does not stabilize and decreases at some point through the end of the pumping test.	This may indicate a recharge boundary has been encountered and would not signify a problem. It may indicate that a surface water body has been encountered and that the source would be designated as groundwater under the influence of surface water (GWI). It may also indicate that the source is located in or adjacent to a leaky aquifer.	The pumping test does not need to be repeated. All of these conditions may have implications for source susceptibility and vulnerability, but do not necessarily suggest a problem for reliability.
Water never clears up (stays turbid) during the pumping test.	This may indicate that the well was inadequately developed or that too coarse a filter pack was placed around the well screen.	Assuming the pumping test was properly conducted, repeating the test would not be necessary. Additional well development may be necessary.
Water starts out clear, but becomes turbid during the pumping test.	This likely indicates that the well was inadequately developed. It may also indicate that groundwater of poorer quality or a surface water body was encountered within the well's area of influence and that water system modification may be necessary.	Pumping test would not need to be repeated. Water system may want to verify this problem as an ongoing concern, however, by repeating the pumping test and establishing its constancy.

Table 4: Constant Rate Discharge Test Problems and Their Significance to Demonstrating Source Reliability

Problem	Significance	Would Repeating Pumping Test Be Advised?
Discharge rate varies during pumping by more than 10%.	Stabilize discharge rate as quickly as possible. Any conditions masked by the flow rate variance may be visible in the recovery data.	Yes, if rate fluctuated frequently by more than 10% and recovery data was not collected.
Data collection does not occur at least at the minimum specified intervals.	Without data collection at sufficient frequency, it is very difficult to establish what aquifer conditions may be affecting groundwater flow.	Yes
Well is pumped dry because pump was placed too close to static water level.	For the pumping tests, the pump should be placed as far below the static water level as possible without placing it within the screened interval of the well. This allows the maximum possible drawdown and maintains some degree of well efficiency.	Yes, unless it occurred very late into the test (for example, at 24 hours or later) and it is apparent that drawdown was in the process of stabilizing. In most cases, however, the test would need to be repeated.
Well is pumped dry because the pumping rate is unsustainable.	This may reflect that either the pumping rate or duration needs to be reduced.	Depends at what point in the test the well was dewatered and the slope of the time verses drawdown curve for the data that has been collected. If pumping time was less than 18 hours, the test will probably need to be repeated.
Drawdown does not stabilize and shows continued increase.	There is no remedy, short of reducing the pumping rate until equilibrium is reached with recharge. The pumping test should be completed with collection of recovery data, as this may be a particularly key component in establishing source reliability.	This is very much a case-by-case situation. If recovery is very slow, the pumping test may need to be repeated at a lower pumping rate to demonstrate source reliability.
Water levels do not recover or exhibit limited recovery after pumping test.	This may be observed in conjunction with continuous, excessive drawdown during the pumping test. This could indicate that the aquifer has a very limited recharge area, the aquifer is of small areal extent, or of limited hydraulic continuity.	The pumping test has revealed significant limitations of the aquifer and repeating the pumping test would probably not provide new information. Conducting the pumping test at a lower rate may be necessary to determine new storage and pumping criteria.
Drawdown does not stabilize and decreases at some point through the end of the pumping test.	This may indicate a recharge boundary has been encountered and would not signify a problem. It may indicate that a surface water body has been encountered and that the source would designate as groundwater under the influence of surface water (GWI).	The pumping test does not need to be repeated.
Water never clears up (stays turbid) during the pumping test.	This may indicate that the well was inadequately developed or that too coarse a filter pack was placed around the well screen.	Assuming the pumping test was properly conducted, the test would not need to be repeated. Additional well development may be necessary.

Problem	Significance	Would Repeating Pumping Test Be Advised?
Water starts out clear, but becomes turbid during the pumping test.	Although, this may indicate that the well was inadequately developed, it probably indicates that groundwater of poorer quality or a surface water body was encountered within the well's area of influence and that water system modifications may be necessary.	Pumping test would not need to be repeated. Water system may want to verify this problem as an ongoing concern, however, by repeating the pumping test and establishing its constancy.

Observation Wells

Other wells in the vicinity and open to the same aquifer as the test well should be used as observation wells, whenever possible. The use of observation wells greatly enhances the ability to obtain more representative and accurate data during the test. Pre-test analysis of well depth and distance can determine the best wells to use for observation. If the aquifer being evaluated is confined, it may be useful to select an additional observation well completed within the overlying unconfined aquifer to determine whether there is any leakage from the overlying aquifer into the confined water system. For saltwater intrusion determinations, observation wells positioned between the pumping well and saltwater body provide the most useful information. Information collected from observation wells is desirable, however, regardless of whether well positioning is optimal.

Stream Stage

If there is a stream near the well being tested, and the conceptual model or simulation suggests a potential connection, the stage (depth and width) of that stream should be periodically monitored for changes during the pumping test period. The relative size and distance of the surface water body with respect to the proposed pumping rate should be considered when evaluating the usefulness of conducting stream stage measurements.

Pre-pumping Phase

The well to be tested should be at its "normal" static water level prior to the test. Water level measurements should be made at 24, 16, 12, 3, 2, and 1 hours prior to initiating pumping. Within the hour immediately preceding pumping, water level measurements should be taken at 20-minute intervals to establish any short-term trends in water level changes that may be occurring. Barometric measurements of atmospheric pressure (inches of mercury) should be made as well. These measurements will allow appropriate corrections to be applied to the drawdown data. In settings where tidal influences may affect the pumping test results, measurements should be made at a frequency sufficient to correct the pumping test drawdown data for any observed tidal influences.

Pumping Phase

After initiation of the pumping test (regardless of pumping test method used), drawdown measurements in the production and observation wells should be recorded according to the schedule below. The greatest numbers of measurements are made within the first 100 minutes when the water levels are changing rapidly. The time intervals given are suggested minimums; more frequent measurements can assist with pumping test analysis and interpretation.

Time After Pumping Started For Constant Rate Test And After Pump Shut Off For Recovery	Time Intervals To Measure Water Levels And Record Data
0 to 10 minutes	1 minute
10 to 60 minutes	5 minutes
60 to 240 minutes	30 minutes
240 to 600 minutes	60 minutes
600 to 1440 minutes	120 minutes

Recovery Phase

Water level measurements obtained during the recovery phase are of equal or greater importance than those collected during the pumping phase because it can confirm any disturbances to flow. In addition, unlike the pumping phase where variation in discharge rate can affect the observations, the recovery phase is not subject to induced variations and can provide more reliable information. Water level measurements made during the recovery phase of the aquifer after the pump has been turned off should be taken at the same frequency as the drawdown measurements during the pumping phase. Do not remove the pump until the test is completely done, including the recovery phase. Measurements should commence immediately upon pump shut down and continue for the same duration as the pumping phase, or until the water levels have reached 95 percent of the initial, pre-pumping static water level. A check valve should be used to prevent backflow of water in the riser pipe into the well, which could result in unreliable recovery data.

Stabilization

Stabilization is defined as less than 0.1 foot of drawdown fluctuation/hour in 4 hours of drawdown measurement.

Measurement Considerations

Water level measurements should be determined to the nearest 0.01 foot. Because of the frequency of measurement required during the initial portion of the test, electronic water level indicators marked in tenths and hundredths of a foot should be used. Data loggers and pressure transducers provide the most accurate measurements and are the easiest to use after initial setup, although, they can add considerable expense to the test.

Conveyance of Pumped Water

There is no fixed rule on how far the water produced during the pumping test should be discharged from the vicinity of the well. It is best to pipe the water outside of the area likely be influenced by the pumping test. The objective of conveying pumped water as far from the site as possible is to minimize the possibility of artificially recharging the aquifer and producing an erroneous pumping test or at least affecting the later stages of the test. This is particularly important when conducting pumping tests in shallow unconfined aquifer settings. Considerations for determining a suitable distance include:

- Is the aquifer confined? If so, less distance will be necessary.
- The duration of the pumping test: the shorter the test, the less distance necessary.
- Depth to water and nature of geologic materials overlying the water producing materials: the greater the depth to water, the less distance necessary; and, the more transmissive the aquifer materials, the greater distance necessary.
- If at all possible, do not discharge conveyed water between the pumping test well and any observation wells or any suspected flow boundaries.

References

The following is an incomplete list of references that provide information and methodologies suitable for designing and analyzing a pumping test.

American Society for Testing and Materials (ASTM). 1997. *D4043-96 Standard Guide for Selection of Aquifer Test-Method in Determining of Hydraulic Properties by Well Techniques*.

Dawson, K. J., and Istok, J. D., 1991. *Aquifer Testing, Design and Analysis of Pumping and Slug Tests*. Lewis Publishers, Inc. 121 South Main Street, Chelsea, Michigan, 48118.

Driscoll, F.G. 1986. *Groundwater and Wells*. Published by Johnson Division, St. Paul, Minnesota 55112.

U.S. Geological Survey (USGS). 1983. *Basic Ground-Water Hydrology*, Water Supply Paper 2220. United States Government Printing Office.

DOH Step Drawdown Pumping Test Procedure

Objective

To evaluate well performance and determine the specific capacity of the well, aquifer transmissivity, and yield. This information will allow a determination of the optimal pump settings (depth and pumping rate) in the well.

Elements

1. It is recommended that a qualified water professional oversee testing of the well and review data analysis and interpretations.
2. An access port to allow depth to water measurements, as described in WAC 173-160-355, must be installed and maintained, if not already present.
3. The step drawdown test should consist of a minimum of four consecutive constant rate discharge steps, with each step utilizing a higher pumping rate. Each step should be conducted for at least 60 minutes. *Some water systems may be eligible to conduct the last step of the step drawdown test according to Step 8.*
4. The step drawdown test should utilize the *maximum design pumping rate* as the third step. The remaining pumping rates should be determined by multiplying the maximum design rate by 0.50, 0.75, and 1.25.
5. Drawdown should be measured in the pumped well at least at the frequency given below:

Time After Pumping Started	Time Intervals
0 to 10 minutes	1 minute
10 to 60 minutes	5 minutes
60 to 240 minutes	30 minutes
240 to 600 minutes	60 minutes
600 to 1,440 minutes	120 minutes

6. Water samples must be collected from the source using proper sampling procedures and analyzed by an accredited laboratory (WAC 246-290-130(3)(g)), unless a constant rate discharge test will be conducted. Water samples should be taken within the last 15 minutes of pumping and must be analyzed for the following water quality parameters:

Group A Water System Type		
Community	**Nontransient Noncommunity**	**Transient Noncommunity**
Bacti/Col	Bacti/Col	Bacti/Col
IOCs	IOCs	IOCs
VOCs	VOCs	VOCs
SOCs	SOCs	--
Rad	--	--

- Bacteriological/coliform (Bacti/Col).
- Inorganic chemicals (IOCs).
- Volatile organic chemicals (VOCs).
- Radionuclide tests.
- Synthetic organic chemicals (SOCs); unless the source qualifies for a waiver, exempting the source from analysis of all or a partial list of SOCs.

7. Recovery should be measured beginning at the end of the last step and measured until the water level has returned to within 95 percent of the initial, pre-pumping static water level. Measurement frequency should conform to the specifications above. The pump should not be removed until the water level has returned to 95 percent of the pre-pumping static water level.
8. *Applicable to only some water systems*. Low water demand sources, which are completed in high productivity aquifers may continue to record drawdown measurements during the last step until stabilization occurs. Measurements should be recorded at the frequency specified in the above table. Stabilization means less than 0.1 foot of drawdown fluctuation per hour in 4 hours of drawdown measurement. The data from this final step should be used to plot the time versus drawdown graph and to determine transmissivity, storage coefficient, and hydraulic conductivity. Generally, stabilization should occur quickly in this type of aquifer setting. Water systems meeting these conditions and running the last step to stabilization do not need to also run a minimum 24-hour constant rate discharge test. In most instances, the appropriateness of this approach should be able to be identified before running the step-drawdown test by reviewing previously conducted tests in the area that are specific to the aquifer.
9. Determine the maximum pumping rate and pumping depth as established from the step drawdown test. Use these values for conducting the constant rate discharge test, if the test is applicable.
10. When the pumping test is completed and if a constant rate discharge test will not be conducted, the data should be compiled into a report and submitted to DOH. The project report guidelines for a groundwater source of supply are in Section 7.3 and Appendix F. Reporting guidelines specific to pumping tests include the following:

a. All data on pumping rates and water levels (including static water levels) from the pumping test and recovery period, and appropriate graphical presentations of the data.

b. The report should determine the following hydraulic parameters; transmissivity or coefficient of transmissibility, hydraulic conductivity or coefficient of permeability, and storativity or coefficient of storage.

c. A map and description (¼, ¼, Section Township Range) accurately indicating the well location, as well as the land surface elevation to the nearest foot above sea level. Address and parcel number should also be provided.

d. Summary, conclusions, and recommendations from the engineer or hydrogeologist regarding pump settings and source reliability

e. A well construction report (well log) for the pumping well and all observation wells.

f. Distance, to the nearest foot, from pumping well to all observation wells and a map indicating all well locations.

g. A copy of all laboratory test results.

DOH Constant Rate Discharge Pumping Test Procedure

Objective

To determine the capability of the well and aquifer to provide a reliable yield of water at the desired rate. Sources with the potential for seawater intrusion should also conduct the additional elements provided at the end of this document.

Elements

1. It is recommended that a qualified water professional (hydrogeologist or engineer) oversee testing of the well.
2. An access port to allow depth to water measurements, as described in WAC 173-160-355, must be installed and maintained, if not already present.
3. The source should be pump tested at no less than the maximum rate determined from the step drawdown test. The constant rate discharge test should not be conducted until after the water levels in the aquifer have achieved at least 95 percent recovery from the step drawdown test pre-pumping static water level conditions.

   Note: *Bailer tests, air lift tests, and slug tests are not acceptable. They do not sufficiently stress the aquifer and are too limited in areal extent.*
4. The duration of the constant rate discharge test should be a minimum of 24 hours. If, at 24 hours, four hours of stabilized drawdown have been observed, the pump may be shut off and measurements of recovery begun. If stabilized drawdown has not been observed within a total of 36 hours, the pump may be shut off and recovery measurements begun. Stabilization is defined as a drop in water level of less than or equal to 0.1 feet per hour.
5. Drawdown should be measured in the pumped well at least at the frequency given below:

Time After Pumping Started	Time Intervals
0 to 10 minutes	1 minute
10 to 60 minutes	5 minutes
60 to 240 minutes	30 minutes
240 to 600 minutes	60 minutes
600 to 1,440 minutes	120 minutes

6. Drawdown in observation wells should be measured, if such wells are available and the information is necessary. Table 2 in Appendix E provides information about aquifer settings for which collection of information from observation wells is encouraged.
7. Water samples must be collected from the source using proper sampling procedures and analyzed by an accredited laboratory (WAC 246-290-130(3)(g)), unless the samples were collected during the step drawdown pumping test. Water samples must be taken within the last 15 minutes of pumping and analyzed for the water quality parameters as follows:

Group A Water System Type		
Community	**Nontransient Noncommunity)**	**Transient Noncommunity**
Bacti/Coli	Bacti/Coli	Bacti/Coli
IOCs	IOCs	IOCs
VOCs	VOCs	VOCs
SOCs	SOCs	--
Rad	--	--

- Bacteriological/coliform (Bacti/Coli).
- Inorganic chemicals (IOCs).
- Volatile organic chemicals (VOCs).
- Radionuclide tests.
- Synthetic organic chemicals (SOCs); unless the source qualifies for a waiver, exempting the source from analysis of all or a partial list of SOCs.

8. Pumping should be followed by collection of recovery data until 95 percent recovery of the pre-pumping static water level has been achieved. Recovery measurements should be made in the same manner and at the same frequency as drawdown measurements. To facilitate accurate recovery data collection, the water system should incorporate backflow check-valve(s) that prevents water within the riser pipe from flowing back into the well when the pump is shut off.
9. When the pumping test is completed, the data should be compiled into a report and submitted to DOH. The project report guidelines for a groundwater source of supply are in Section 7.3 and Appendix F. Reporting guidelines specific to pumping tests include the following:

   a. All data on pumping rates and water levels (including static water levels) from the pumping test and recovery period, and appropriate graphical presentations of the data.

   b. The report should determine the following hydraulic parameters: transmissivity or coefficient of transmissibility, hydraulic conductivity or coefficient of permeability, and storativity or coefficient of storage

   c. A map and description (¼, ¼, Section Township Range) accurately indicating the well location, as well as the land surface elevation to the nearest foot above sea level. Address and parcel number should also be provided.

   d. Summary, conclusions, and recommendations regarding pump settings and source reliability.

   e. A well construction report (well log) for the pumping well and all observation wells.

   f. Distance, to the nearest foot, from pumping well to all observation wells and a map indicating all well locations.

g. A copy of all laboratory test results.

Additional Steps for Potential Seawater Intrusion Areas

a. For the source well (the well pumped during the aquifer test), chloride and conductivity samples should be collected at the following intervals: one sample during the initial 30 to 60 minutes, one sample during the 6th hour (360 to 420 minutes), one sample during the 12th hour (720 to 780 minutes), and one sample within the last 15 minutes of the aquifer test pumping phase.

b. For at least one observation well, two chloride and conductivity samples should be collected, one base sample prior to initiation of the aquifer test and one sample upon completion of recovery data collection. Any observation well sampled should be purged of three well casing volumes prior to sample collection. Following collection of the base sample, observation wells should be given adequate time to recover to static water level prior to initiation of the aquifer test.

Note: *It is recommended that a field test kit be used to monitor chloride levels within the pumping well during the pumping phase.*

In addition to the reporting requirements in Item 9 above, the following should also be included in the report:

1. Tidal influence on the pumping well. Data on pumping water levels, chlorides, and tidal fluctuations (corrected to point) should be plotted on a single graph with respect to time.
2. Potential for seawater intrusion into this or other seaward wells.

Pumping Test Data Collection Sheet

Water System ID:	Owner:	Well Tag No.:
DOH Source ID:	Water System Name:	Well Name:
Type of Test:	Conducted By:	Date:
Static Water Level (as measured from reference point):		County:
Observation Wells?		Well Elevation (MSL):
Distance of observation well (r) from pumped well (ft):		

Time	**Time (t) since pumping began (min)**	**Depth to Water Level (ft)**	**Drawdown (ft)**	**t/r^2**	**Pumping Rate (Q) (gpm)**	**Comments**

Recovery Data Collection Sheet

Water System ID:	Owner:	Well Tag No.:
DOH Source ID:	Water System Name:	Well Name:
Type of Test:	Conducted By:	Date:
Static Water Level (as measured from reference point):		County:
Observation Wells?		Well Elevation (MSL):
Distance of observation well (r) from pumped well (ft):		

Time	**Time (t) since pumping began (min)**	**Time (t') since pumping stopped (min)**	**t/t'**	**Depth to Water Level (ft)**	**Residual Drawdown (ft)**	**Comments**

Appendix F: Obtaining Approval for Wells as Drinking Water Sources

I. Applicability

The following guidance helps to outline and describe the process to be followed when an applicant seeks approval for developing a new well as a drinking water source. This guidance is based on the requirements in chapter 246-290 WAC.

The following guidance also applies to sources serving existing, unapproved water systems. If the source is an existing well proposed to be converted into an "approved" water source, information requested by DOH that is not available (such as a missing well log) should be brought to the attention of the reviewing engineer.

The source approval process for a new well generally consists of three steps:

- DOH reviews and approves a project report prepared for the water utility by a professional engineer licensed in Washington State.
- DOH reviews and approves the construction documents prepared by a licensed professional engineer for the facilities required to place the well into operation.
- A licensed professional engineer submits a *Construction Completion Report Form* (DOH 331-121) followed by an acknowledgment from DOH that the source was developed properly and is ready to begin operation.

The first two steps above are often performed concurrently.

Note: *This guidance does not specifically address the more complicated and less common source approvals for development of:*

- *Springs.*
- *Groundwater under the direct influence of surface water.*
- *Surface water.*

The underlying philosophy for evaluating a proposed drinking water source is that the applicant should only use drinking water from the highest quality source feasible. DOH has developed "pre-drilling" guidance such that an applicant may make informed decisions regarding the safety and reliability of a well prior to investing time and resources in its construction. DOH is available to help the applicant evaluate the pre-drilling information. However, DOH can approve a source as a potable water supply only after reviewing all information and data outlined in the following well source approval checklist.

II. Pre-Drilling Guidance

A. **Prior to drilling a well,** the applicant **must**:

1. Obtain a notice of intent to construct a well from the Department of Ecology (WAC 173-160-151).
2. Ensure that a licensed well driller will drill the well and that the well will be constructed according to chapter 173-160 WAC.
3. Obtain a well site inspection by state or local health jurisdiction staff (WAC 173-160-171(3)(c)).

B. **Prior to drilling a well,** the applicant **should**:

1. Evaluate the possibility of obtaining alternate sources of supply through interties with neighboring utilities or wells already in existence.
2. Conduct a preliminary hydrogeologic assessment, which includes a Wellhead Protection Potential Contaminant Source Inventory (see Section IV: Supplemental Information).
3. Contact DOH to learn the parameters used to delineate groundwater under the direct influence of surface water (GWI). A determination of the GWI status is required prior to source approval. If a well meets DOH's criteria for a potential GWI (for example, less than 50 feet deep and within 200 feet of a surface water body), data will be required to determine whether the source is hydraulically connected to surface water and to what extent. DOH will be involved with approval of the intended monitoring plan for the data collection (see Note 1 below).
4. Obtain a legal right through an ownership option or recorded covenant to prevent potential sources of contamination from being located within the standard sanitary control area (normally a 100-foot radius around the well) (see Note 2 below).

Note 1: *Weekly temperature and conductivity measurements of the well water (and any nearby surface water) collected over a period that captures seasonal influences, and possibly the results of up to four microscopic particulate analyses of the proposed source, are required to evaluate whether the source is GWI. As an alternative to weekly temperature and conductivity monitoring, the scope of the hydrogeologic assessment may be expanded to include a comprehensive evaluation of the relationship between groundwater aquifer characteristics and nearby surface water. The hydrogeologic assessment should discuss the well characteristics, site specific modeling results, the hydraulic gradient, the presence/absence and affect of adjacent wells, and water quality test results.*

Note 2: *If there is a concern about controlling the entire sanitary control area (SCA), or if a reduction in the size of the SCA is being considered, this should be discussed with DOH at the time of the well-site inspection. This ensures an opportunity to evaluate site conditions and allows for the identification of possible mitigation measures—such as providing a deeper surface seal during well construction.*

III. Supplemental Information

Conducting Hydrogeologic and Susceptibility Assessments, Wellhead Protection Area (WHPA) Delineations, Potential Contaminant Inventory and Pumping Tests

To evaluate the appropriateness of a proposed drilling location, a preliminary susceptibility assessment, preliminary WHPA delineation and initial contaminant inventory should be conducted. Findings should be mapped.

A preliminary susceptibility assessment provides the applicant, and DOH, information prior to drilling a well that helps evaluate the suitability of the proposed well site before a significant expenditure of resources occurs. It may be helpful to contact DOH for guidance regarding conduct of a preliminary susceptibility assessment before selection of a potential well site. Elements that are unknown until after drilling occurs should have their values estimated based on site specific conditions and best professional judgment (length of screen, confined vs. unconfined aquifer, and other parameters).

The initial WHPA delineation can be done using the "Calculated Fixed Radius" method. More sophisticated and accurate methods of delineation, such as analytical or numerical modeling, are encouraged. See DOH *Wellhead Protection Program Guidance Document* (331-018) for further explanation of these methods. Contact your DOH regional office (Table 1-1) for a copy of the guidelines. The WHPA delineation should identify the six-month, one-, five- and ten-year time of travel boundaries. A survey for potential sources of groundwater /source water contaminant should be conducted in the WHPA area.

When the well has been drilled, it must be tested to show it is physically and reliably capable of delivering water in the necessary quantities. Refer to DOH guidelines for conducting pumping tests.

If a susceptibility assessment was done prior to drilling, it should be updated—with the previously estimated values replaced with the true numbers derived from the well log (such as length of screen, degree of confinedness, results from the water quality analysis). This will also result in a new wellhead delineation and possibly require an update of the potential contaminant source inventory.

If the findings of the pumping test or hydrogeologic assessment indicate that the proposed source is potentially GWI the proposed source needs to be evaluated to identify whether or not it is GWI prior to source approval by DOH.

Sanitary Control Area Determination

Before drilling, it is prudent to ensure that you have the ability to control the standard sized sanitary control area (SCA) (100' radius around well) through a protective covenant or other mechanism. While the SCA size may occasionally be able to be reduced based on post-drilling analysis and findings, there should not be an assumption made that such a reduction will occur.

DOH will not approve the source without demonstrable evidence that the purveyor can control and protect the sanitary control area.

Concern about controlling the entire SCA, or considering a reduction in the size of the SCA, should be raised to the DOH representative at the time of the preliminary site inspection **prior to the well being drilled**. This ensures an opportunity to evaluate siting conditions and allows for the identification of possible mitigation measures, such as a deeper surface seal during well construction.

The SCA must have a radius of 100 feet, unless justification demonstrates that a smaller area can provide an equivalent level of source water protection. The justification should address geological and hydrological data, well construction details, mitigation measures and other relevant factors necessary to ensure adequate source water quality protection. Major factors influencing a decision to allow a smaller than standard SCA include depth of the screened interval and "confinedness" of the water bearing zone being used. DOH may require a larger SCA, additional mitigation measures, or both if land use, geological or hydrological data support such a decision.

Prior to receiving DOH approval of the proposed source the purveyor must be able to provide the dimensions, location, and legal documentation of the SCA. Legal control of the SCA is key because the purveyor is required to "control" the SCA to prevent any potential source of contamination from being constructed, stored, disposed of, or applied within the sanitary control area. To ensure the purveyor can control the SCA, the purveyor is required to either own the SCA outright, or the purveyor must have the right to exercise complete sanitary control of the land through other legal provisions, such as a duly recorded declaration of covenant, restricting the use of the land.

IV. Methods to Physically Protect the Wellhead

Physical protection of wellheads can be accomplished by several methods depending on the specific situation. One of the most effective methods is enclosing the wellhead in a well house. If such a facility is not feasible, other measures should be initiated to provide physical protection to the wellhead. Standard protections include:

- Construction of a well house.
- Permanent security fencing.
- Use of an approved pitless adapter or well cap approved by DOH.

Note: *"Pitless adapter" means a commercially manufactured device designed for attachment to openings through the casing of a water well that permits water service pipes to pass through the wall or an extension of a casing and prevents the entry of contaminants into the well or water supply.*

Additional physical protections include:

- Three metal posts at least three inches in diameter, and set in concrete, can be installed in a triangular array around the casing and at least two feet from it. Each post should extend at least three feet above and below the ground surface.
- A reinforced concrete pad can be installed to prevent freeze/thaw cracking of the surface seal. When a concrete pad is used, the well seal should be part of the concrete pad.

Where there is concern about possible flooding around the wellhead, the following measures may be warranted:

- Raise the wellhead at least 2 feet above the 100-year flood level.
- Protect air intakes by using “snorkel” valves.
- Identify and avoid the active channel of the river/flood plain during the well-siting process. Ensure location meets county flood hazard regulation requirements.

Construction Documents

As required under WAC 246-290-120 for approval of construction documents, the following items must be addressed:

1. **Well Construction Details**: Refer to the Department of Ecology’s well construction standards, chapter 173-160 WAC.
2. **Pump Installation and Well House Details:**
    a. Justification for the proposed type and size of pump, if not part of the project report.
    b. Pump control logic.
    c. Emergency alarm systems.
    d. Casing and well house slab elevations and slope of floor.
    e. Sample taps to enable collection of a sample before and after treatment.
    f. Provisions to discharge wastewater in a manner acceptable to the Department of Ecology and local authorities. Acceptable disposal methods will depend upon local site conditions and may include discharge to a sanitary sewer with appropriate cross-connection control assembly, overland flow, or to a lake or stream.
    g. Source meter capable of recording total time-related discharge (WAC 246-290-130(4)(g)), and rates of flow registers are recommended. Well fields should be designed such that total flow from the well field can be measured; however, it is not necessary to meter each individual source in the well field.
    h. Valving.
    i. Pressure gauges.
    j. Screened and inverted well vent.

k. Water level measuring device.
l. Electrical connections to allow the use of emergency power.
m. Sufficient pump house ventilation to provide for avoidance of thermal overload of pump motors.
n. Routine operations and maintenance requirements.

Note: *Oil lubricated turbine pumps are not considered to be acceptable.*

V. Additional References

The following references are pertinent in obtaining the approval of a well as a source of drinking water:

a. Chapter 246-290 WAC, Group A Public Water Supplies
b. DOH "Recommended Pumping Test Procedures"
c. DOH Susceptibility Assessment Survey Form (Version 2.2)
d. DOH Susceptibility Assessment Support Packet
e. Washington State Wellhead Protection Program (1995)
f. Washington State Inventory of Potential Contaminant Sources in Washington's Wellhead Protection Areas (1993)
g. Covenants for Public Water Supply Protection (2007)
h. DOH - Potential GWI Sources – Determining Hydraulic Connection Through Water Quality Monitoring (2003)
i. DOH - Potential GWI Sources – Microscopic Particulate Analysis (2003)
j. Department of Ecology Well Construction Guidance Packet

Note: *For more information, or to get copies of these materials, contact the appropriate DOH regional office (see Table 1-1).*

Table 1: A Partial List of Potential Contaminant Sources (Sorted by Process)

CATEGORY I—Sources designed to discharge substances

Subsurface percolation (such as septic tanks and cesspools)
Injection Wells
Hazardous materials
Non-hazardous materials (such as brine disposal and drainage)
Non-waste (such as enhanced recovery, artificial recharge solution mining, and in-situ mining)
Land application
Wastewater (such as spray irrigation)
Wastewater byproducts (such as sludge)
Hazardous waste
Non-hazardous waste

CATEGORY II—Sources designed to store, treat, or dispose of substances; discharge through unplanned release

Landfills
- Industrial hazardous materials
- Industrial non-hazardous materials
- Municipal sanitary

Open dumps, including illegal dumping (waste)
Residential (or local) disposal (waste)
Surface impoundments
- Hazardous materials
- Non hazardous materials

Waste tailings
Waste piles
- Hazardous materials
- Non hazardous materials

Materials stockpiles (non-waste)
Graveyards
Animal burial
Above ground storage tanks
- Hazardous materials
- Non-hazardous materials
- Non-waste

Underground storage tanks
- Hazardous materials
- Non-hazardous materials
- Non-waste

Containers
- Hazardous materials
- Non-hazardous materials
- Non-waste

Open burning sites
Detonation sites
Radioactive disposal sites

CATEGORY III—Sources designed to retain substances during transport or transmission

Pipelines
- Hazardous materials
- Non-hazardous materials
- Non-waste

Materials transport and transfer operations
- Hazardous materials
- Non-hazardous materials
- Non-waste

CATEGORY IV—Sources discharging substances as a consequence of other planned activities

Irrigation practices (such as return flow)
Pesticide applications
Fertilizer applications
Animal feeding operations
De-icing salts applications
Urban run-off
Percolation of atmospheric pollutants
Mining and mine drainage
- Surface mine-related
- Underground mine - related

CATEGORY V—Sources providing conduit or inducing discharge through altered flow patterns

Production wells
- Oil (and gas) wells
- Geothermal and heat recovery wells
- Water supply wells

Other wells (non-waste)
- Monitoring wells
- Exploration wells

Construction excavation
Improperly abandoned wells

CATEGORY VI—Naturally occurring sources whose discharge is created or exacerbated by human activity

Groundwater- surface water interactions
Natural leaching
Saltwater intrusion/brackish water upcoming (or intrusion of other poor-quality natural water)

Note: *Only sources that pose possible threats to the drinking water supply need to be documented in the inventory.*

Iron and Manganese Removal Facilities for Small Water Systems Submittal Checklist

Washington State Department of Health

This checklist is to help with design and installation of iron (Fe) and manganese (Mn) treatment facilities for small water systems using groundwater sources. Various surveys of iron and manganese treatment facilities in the USA show that only 50 to 60 percent of the facilities were successful in meeting drinking water standards for Fe and Mn. Several factors leading to poor treatment performance are listed below. Factors like these are important to consider when designing a treatment facility.

- Iron complexation with humic substances or with silica.
- The oxidation pH is too low.
- The effective size of the filtration media is too large.
- The oxidation time is too short.
- Lack of accurate raw water analysis at time of design.
- Incorrect oxidant dosage applied.
- Filtration rate is too high.
- Inadequate backwashing leading to filtration media failure.

Because of the many factors affecting design, and because the raw water quality is so critical to selecting an appropriate treatment technique, all Fe and Mn treatment facilities should be pilot plant tested at the site with certain raw water quality tests performed.

Where appropriate, any supporting documentation applicable to a checklist element is to be included with submission of the following checklist.

1. General Water System Information

____ ____________________________
Water System Name ID Number County

____ ____________________________
Owner Name Owner Phone Number

____
Owner Address (including city, state, and zip)

____
Owner E-mail

Manager Name | Manager Phone Number

Manager Address (including city, state, and zip)

Manager E-mail

2. Description of Problem

Briefly describe the problem. What is the purpose of the proposed treatment? What are the goals of the treatment plant? (Attach additional sheets if necessary).

3. Raw Water Quality

A minimum of two separate measurements are required for total Fe, ferrous Fe, Mn, total organic carbon (TOC), hardness, alkalinity, pH, and temperature. Temperature, alkalinity ferrous iron and pH measurements must be performed at the well site (in the field) by a qualified person. All other water quality parameters should be analyzed by a laboratory that is state certified for drinking water. **All lab data sheets must be attached**.

Water Quality Parameters	#1	#2	#3	Method/Test Used	Calibration
Date/Time				N/A	N/A
Total Iron (Fe) (mg/l)					
Ferrous Fe (Fe+2) (mg/l)					
Manganese (mg/l)					
Hardness (mg/l of CaCO3)					
Alkalinity (mg/l of CaCO3)					
TOC (mg/l)					
Temperature (Celsius)					
PH					

*** Attach complete inorganic chemistry and TOC test results. Attached? ☐ Yes ☐ No**

4. Type of Treatment Option Chosen

☐ Ion Exchange / Water Softener
☐ Aeration and Filtration
☐ Chlorination and Filtration
☐ Potassium Permanganate and Filtration (Manganese Greensand Filter)

Mode of operation if using manganese greensand filters? Check one.

☐ Continuous
☐ Batch
☐ N/A

5. Pilot Filter Results

Removal Performance data (Minimum of two test results needed):

Test #	Time Date	Raw wtr Fe	Trtd Wtr Fe	% Fe Remvd	Raw Wtr Mn	Trtd Wtr Mn	% Mn Rmvd	< Fe MCL Y-N	< Mn MCL Y-N	Trtd Watr Temp
1										
2										
3										
4										

How long was the pilot plant operated? _____ Days _____ Hours

What was the treatment rate of the pilot plant? _____ gpm/sq. ft _____ gpm

The following questions must be completed for all oxidation and filtration techniques:

Was pH adjustment necessary? ☐ Yes ☐ No

What was the oxidation chemical dose used? _____ mg/l

If air was used as the oxidant, what volume of air was required? _____ cu. ft/gal _____ N/A

How much oxidation contact time was provided? _____ minutes
Oxidation contact time is detention time from point of oxidation addition to the filter.

6. Treatment System Details

Provide a written description of the proposed treatment plant with specifications. Include an appropriately labeled diagram. The description should include flow rates, chemical doses needed, facility size, and how backwash or regeneration will be accomplished. (Attach additional sheets as necessary).

6.a. Ion Exchange (if applicable)

Resin/Media

What type of resin is proposed? (check one)
☐ anion
☐ cation
☐ combined
☐othe

Please explain your choice:

____

____

____

Manufacturer's brand name (if applicable) ____

NSF approved? ☐ Yes * ☐ No
*Attach copy of NSF approval listing.

Treatment Rate

Maximum flow rate to be treated _____ gpm (attach pump curve)

Manufacturers recommended treatment unit application rate _____ gpm/sq. ft

Area of treatment unit(s) proposed _____ sq. ft

Actual application rate (max flow / area) _____ gpm/sq. ft

Actual application rate < recommended? ☐ Yes ☐ No

Actual application rate < pilot filter rate ☐ Yes ☐ No

Regeneration Requirements

Describe regeneration process in detail

____

____

____

How will regeneration be triggered?

____

____

Describe how the regeneration solution is made.

____

____

____

Are resin cleaning compounds going to be used? ☐ Yes ☐ No

Compound name ______________________

NSF approved? ☐ Yes * ☐ No
*Attach copy of NSF approval listing.

6.b. Ion Exchange (if applicable)

6.b.1. Filter Media

What is the filtration media made of (for example, type of material)?

____

____

Does the media have NSF approval? ☐ Yes * ☐ No
*Attach copy of NSF approval listing.

6.b.2. Filter Rate

Maximum flow rate to be treated _____ gpm (attach pump curve)

Manufacturers recommended treatment unit application rate _____ gpm/sq. ft
Must be less than 5 gpm/sq. ft for most filtration media and less than 15 gpm/sq. ft for solid manganese dioxide filtration with extensive pilot testing at this high rate.

Area of treatment unit(s) proposed _____ sq. ft

Actual application rate (max flow / area) _____ gpm/sq. ft

Actual application rate < recommended? ☐ Yes ☐ No

Actual application rate < pilot filter rate☐ Yes ☐ No

6.b.3. Backwashing Requirements

Manufacturers recommended backwash application rate _____ gpm/sq. ft
Must be greater than 12 gpm/sq. ft for most filtration media and greater than 32 gpm/sq. ft for solid manganese dioxide media.

System's backwash output at working pressure of _____ psi _____ gpm

Backwash pump pressure ______ psi (attach pump curve)

Area of treatment unit(s) proposed _____ sq. ft

Actual backwash rate (pump output / area of filter) _____ gpm/sq. ft

Actual backwash rate > recommended? ☐ Yes ☐ No

Does backwash cycle include surface scour? ☐ Yes ☐ No

Does backwash cycle include air application? ☐ Yes ☐ No

6.b.4.1. Oxidant Chemical Feed Pump (if applicable)

Manufacturer's specifications attached ☐ Yes ☐ No

Make ____________________ Model ____________________

Pressure range of water system (psi) _____ min _____ max

Max injection pressure of pump (psi) _____

Flow range of metering pump (gal/hr) _____ min _____ max

Desired oxidant dose C_S (ppm) _____ (from pilot study)

Proposed feed solution concentration of feed solution (ppm), C_f _____

How do you make the feed solution?

____

____

____

Maximum system flow rate, Q_S(gpm) _____

Required feed pump rate (gallons/hour) = Qf

$$Qf = \frac{(Qs)(Cs)(60)}{Cf} = \_\_\_\_\_\_\_\_\_\_\_\_ \text{ gal/hr}$$

Falls in mid-range of metering pump? ☐ Yes ☐ No

Size of solution tank (gallons) _____

Estimated average usage of solution (gallons/day) _____

Shelf life of feed solution (months) _____

6.b.4.2. Oxidant Injector – Aerator (if applicable)

Manufacturer's specifications attached ☐ Yes ☐ No

Make ____________________ Model ____________________

Pressure range of water system (psi) _____

Volume of air injected at system flows and pressures _____ cu. ft/gal

6.b.5 Oxidant Contact Time

How many minutes are required for the oxidant to completely oxidize Fe and Mn at the pH of the system (from pilot plant)? _____ minutes

How much contact time (minutes) is available between the oxidant injection pint and the filter bed at maximum flows? _____ minutes

Is the available contact time greater than required contact time? ☐ Yes ☐ No

6.b.6 pH Adjustment (if applicable)

Is pH adjustment needed to oxidize Fe or Mn within the specified contact time available (from pilot study)? ☐ Yes ☐ No

How will the system raise pH? ____________________

If adding chemicals, attach sizing calculations per Section 6.b.4.1. Attached: ☐ Yes ☐ No

Is using a contact bed: ☐ Yes ☐ No

What type of material is proposed in the bed? ____________________

Attach calculations estimating time to deplete contact bed capacity at system flow rates and pH levels. Attached: ☐ Yes ☐ No

6. b.7 Regeneration Requirements (Manganese Greensand Filters)

Describe regeneration process in detail

____

____

____

How will regeneration be triggered?

____

____

____

Describe how the regeneration solution is made

____

____

____

7. System Hydraulics

a. Required pumping rate to meet system demands _____ (gpm)

b. Required pump head:
    Well (pump) lift _____ ft
    System Elev. Diff. _____ ft
    Trmt. Plant Headloss _____ ft
    System Headlosses _____ ft
    Residual Pressure _____ ft
    TOTAL _____ ft

c. Pump Selected: (attach pump curve and specifications)

Type ____________________ Manufacturer ____________________

Model No. ____________________ RPM ____________________

Horsepower ____________________

Pump rate _____, gpm, at a head of _____ feet

Pump operating efficiency at operating conditions _____ %

8. Backwash / Regeneration Waste Disposal

Where will backwash wastewater be disposed? Wastewater should not be discharged into or near any surface water body or groundwater source. Provide a written description and drawing. Drawing attached? ☐ Yes ☐ No

What is the nearest body of water to the discharge point? Check one.

☐ Well ☐ Stream ☐ River ☐ Lake ☐ Pond ☐ Wetland _____ Other

How far is the nearest body of water? _____ (ft)

Has the Department of Ecology been contacted and is the method of waste disposal acceptable to them and the local authorities? ☐ Yes ☐ No

9. Operational Considerations

Sampling taps for both raw and finished water and after each treatment unit ☐ Yes ☐ No

Totalizer meter to record total volume treated ☐ Yes ☐ No

Flow proportioned feed pump(s) ☐ Yes ☐ No

Solution tank covered and volume calibrated ☐ Yes ☐ No

Fe and Mn test kits in specifications ☐ Yes ☐ No

Plans and specifications attached ☐ Yes ☐ No

O & M Plan attached ☐ Yes ☐ No

10. Submittal prepared by:

Name ______________________________

Address ______________________________

____

____

E-mail ______________________________

Phone ______________________________

Engineer's Signature and Stamp Date ______________________________

Hypochlorination Facilities for Small Water Systems Submittal Checklist
Washington State Department of Health

General Water System Information

Water System Name ______________________ ID Number ______ County ______

Owner Name ______________________ Owner Phone Number ______________________

Owner Address (including city, state, and zip) ______________________

Owner E-mail ______________________

Manager Name ______________________ Manager Phone Number ______________________

Manager Address (including city, state, and zip) ______________________

Manager E-mail ______________________

Description of Problem-Brief description of problem and identification of cause, if known. Previous measures taken to solve problem. (Attach additional sheets if necessary)

____

____

____

Water System Operating Parameters

Max system pressure at chlorine injection point, psi _____

Average daily water use, gallons/day Q_a _____

Flow rate at injection point (for example, installed pump capacity), gpm Q_s _____

Max outflow from chlorine contact chamber (for example, PHD, booster pump), gpm Q_o _____

Required Chlorine Dose

Target free chlorine residual, ppm C_t _____

Estimated chlorine demand (due to organics, iron, and manganese), ppm C_d _____

Describe how demand was determined:

____

____

____

Required chlorine dose, ppm $C_s = C_t + C_d$ C_s _____

Chlorine Feed Pump Requirements

Stock chlorine strength, percent C_c _____

Proposed feed solution:

Amount of chlorine to be added to solution tank, cups V_c _____

Amount of feed solution*, gallons V_f _____

*V_f is the sum of the stock chlorine volume and the volume of added dilution water

Concentration of feed solution, ppm C_f _____

$$C_f = \left(\frac{(C_c)(V_c)(10{,}000)}{(V_f)(16)} \right)$$

Required feed pump rate, gallons/hour Q_f _____

$$Q_f = \left(\frac{(Q_s)(C_s)(60)}{(C_f)} \right)$$

Chlorine Feed Pump Specifications

Make ____________________ Model ____________________

Max injection pressure of metering pump, psi _____

Greater than or equal to maximum system pressure? ☐ Yes ☐ No

Flow range of metering pump, gallons/hour _____ min _____ max

Falls in mid-range of pump? ☐ Yes ☐ No

If no, explain and justify in the comments section.

Solution Tank

Size of solution tank, gallons V_t _____

Estimated time between tank refills, days RT _____

$$RT = \left(\frac{(V_t)(Q_s)(60)}{(Q_f)(Q_a)} \right)$$

Shelf life of feed solution, months _____

Chlorine Contact Time

Minimum contact time for groundwater sources: 30 minutes at 0.2 ppm and 10 minutes at 0.6 ppm (C_txT=6) unless otherwise directed by DOH (WAC 246-290-451).

Note: *Sources designated as groundwater under the influence of surface water must meet the more stringent requirements of WAC 246-290, Part 6. Contact time may not be required if raw water sampling clearly indicates the source is free of contamination. Contact DOH or your local health jurisdiction for more information.*

Have coliform bacteria ever been found in the untreated source water? ☐ Yes ☐ No

Available contact volume (excluding operational and equalizing storage), gallons V_s _____

Baffling efficiency, percent n _____

Use 10 percent for an unbaffled tank with separate inlet and outlet. Use 100 percent for a pipeline.

Calculated contact time, minutes T _____

$$T = \left(\frac{(V_s)(n)}{(Q_0)(100)} \right)$$

Checklist of Additional Required Items *

☐ Sampling taps for both raw and finished water
☐ Source meter to record total volume pumped
☐ Flow proportioned feed pump
☐ Manufacturer's specifications for feed pump
☐ Manufacturer's specifications for meter/feed back loop control system
☐ Solution tank covered and volume calibrated
☐ DPD chlorine test kit in specifications
☐ DOH monthly report forms provided to utility
☐ Plans and specifications attached
☐ Operations and maintenance plan enclosed
☐ Disinfection byproducts monitoring plan enclosed

* All of these items must be included

Comments

Submittal prepared by:

Name ____

Address ____

____

____

E-mail ____

Phone ____

Engineer’s Signature and Stamp Date ____

Fluoride Saturator, Upflow Type Submittal Checklist
Washington State Department of Health

General Water System Information

______________________________	____________________
Water System Name	ID Number
______________________________	____________________
Owner	Phone

____

Address (including city, state, zip, and county)

______________________________	____________________
Manager	Phone

____

Address (including city, state, and zip)

______________________________	____________________
Source No.	Source Name

Water System Operating Parameters

Flow range of source, gpm _____ max _____ min

Required Fluoride Dose

Optimal fluoride level, mg/L _____

Natural fluoride level, mg/L _____

Supplemental fluoride dosage, mg/L_____

NaF Saturator Specifications

Make ____________________ Model ____________________

Saturator tank size, gallons ______

Estimated average usage of solution, gallons/day ______

Estimated 30-day usage of dry crystalline NaF, pounds ______

Make-up Water

Water line
- Pipe size, inches _____
- Static pressure, psi ______
- Flow restrictor capacity, gpm _____

Source protection
- Fixture protection AVB _____
- Premises isolation RPBA _____
- Drain/overflow pipe size, inches _____
- Drain/overflow air gap, inches _____

Water hardness
- Total hardness, mg/L as $CaCO_3$ _____
- Softening treatment type (hardness >50) _____

NaF Solution Feed Pump Specifications (attach manufacturer's specifications)

Make ____________________ Model ____________________

Pressure range of water system at injection point, psi _____ min _____ max

Maximum injection pressure of pump, psi _____

Flow range of metering pump, gal/hr _____ min _____ max

Fluoride feed rate, gal/hr

$$\frac{Capacity(gpm) x Dosage(mg/L) x 60}{18{,}000 mg/L}$$

Required feed rate falls in mid-range of metering pump? ☐ Yes ☐ No

Checklist of Additional Required Items *

- ☐ Sample tap for treated water following mixing
- ☐ Source meter to record total volume pumped
- ☐ Make-up meter to record total solution volume fed
- ☐ Flow proportioned feed pump (with pacing flow meter)
- ☐ Feed pump electrically interconnected with source pump
- ☐ Flow sensing switch in water main interconnected with source pump
- ☐ Antisiphon valve at pump head
- ☐ Antisiphon valve at injection quill
- ☐ ANSI/NSF 60 certification for NaF chemical
- ☐ Dry storage for 30-day supply of chemical
- ☐ Respirator, gloves, apron, goggles provided for handling NaF

☐ Fluoride test kit (SPADNS or ISE) in specifications
☐ DOH monthly report forms provided to utility
☐ Sample bottles for split sampling provided
☐ Plans and specifications attached
☐ Operations and maintenance plan attached

* All these items must be included.

Submittal prepared by:

Name ________________________________

Address ________________________________

____

____

E-mail ________________________________

Phone ________________________________

Engineer's Signature and Stamp Date ________________________________

Ozone Treatment for Removal of Iron and Manganese in Groundwater
Washington State Department of Health

Submittal Checklist

This outline is to help with the design and installation of ozone / filtration treatment facilities for small water systems with groundwater sources containing high iron and manganese.

Various surveys of iron and manganese treatment facilities in the USA have shown that only 50 to 60 percent of the facilities produced water that met drinking water standards for iron (Fe) and manganese (Mn). Several causes of poor treatment performance have been identified and are listed below. These factors affecting treatment should be considered when designing a treatment facility.

- Iron complexation with humic substances or with silica.
- The oxidation pH is too low.
- The effective size of the filtration media is too large.
- The oxidation time is too short.
- Lack of accurate raw water analysis at time of design.
- Incorrect oxidant dosage applied.
- Filtration rate is too high.
- Inadequate backwashing leading to filtration media failure.

Because of the many factors affecting design, and because the raw water quality is so critical to selecting an appropriate treatment technique, all facilities must be pilot plant tested at the site, with certain raw water quality tests also performed on site. Submittals for treatment facilities must be prepared by an engineer licensed in Washington State.

*** All supporting documentation must be included with the checklist.**

Submittal prepared by:

Name ________________________________

Address ________________________________

____

____

E-mail ________________________________

Phone ________________________________

Engineer's Signature and Stamp Date ________________________________

I. **General Water System Information**

Provide the following general information:

- Water system name
- Identification number
- Owner's name
- Address and telephone number
- Manager's name
- Address
- Phone number

II. **Description of the Water Quality Problem**

Describe the source of supply and the purpose and goals of the treatment proposed.

III. **Raw Water Quality**

A minimum of two separate measurements are required for Fe, Mn, TOC, hardness, alkalinity, pH, and temperature. Temperature, ferrous iron and pH measurements must be performed at the well site (not in a lab) by a qualified person. All other water quality parameters must be analyzed by a laboratory certified for drinking water by DOH.

Raw Water Quality Table

Water Quality Parameters	#1	#2	#3	Method/Test Used	Calibration
Date/Time				N/A	N/A
Ferrous Fe (Fe+2) [mg/l]					
Total Iron [mg/l]					
Manganese [mg/l]					
Hardness [mg/l of CaCO3]					
Alkalinity [mg/l of CaCO3]					
TOC [mg/l]					
Temperature [Celsius]					
pH					

All lab data sheets must be attached.

IV. Water Chemistry and Ozone Demand

1. Based on actual water quality results, show ozone demand calculations for the water to be treated.
2. Identify the benefits that can be achieved by the proposed ozone treatment facilities.
3. Identify any adverse effects that the proposed ozone treatment system may have on other water quality parameters (trihalomethane generation, increased corrosivity, and nutrient source for regrowth bacteria).
4. Discuss the effect of the proposed ozone treatment on the requirements of the federal Safe Drinking Water Act (Groundwater Rule and the Stage 1 Disinfection/ Disinfection Byproducts Rule).

V. Summarize Ozone Treatment Components

Include schematic drawing of the treatment system which:

- Identifies major system components,
- Identifies process control stations, such as water quality sampling points, flow meters, and pressure gauges; and
- Identifies location of ambient ozone detectors.

VI. Summarize Pilot Plant Results

1. Describe the pilot plant setup and results as they relate to full scale treatment design.
2. Describe the following pilot plant design parameters:
   a. Treatment rate of the pilot plant (gpm/sq.ft. or gpm).
   b. Ozone dosage (mg/L).
   c. Length of oxidation contact time. Oxidation contact time is detention time from point of oxidation addition to filter.
   d. Was pH adjustment necessary?
3. How long was the pilot plant operated? What seasonal changes in water quality which may effect the performance of the proposed treatment plant.
4. Document removal performance data in the table below; A minimum of two results are required.

Summarize Pilot Plant Results

Test #	Date/ Time	Raw Water Fe	Treated Water Fe	% Fe Removed	Raw Water Mn	Treated Water Mn	% Mn Removed	Complies with Fe MCL	Complies With Mn MCL	Treated Water Temp
1										
2										
3										
4										

All lab data sheets must be attached.

VII. Summarize the Existing System Limitations

Identify the limiting capacity of the existing system (source, storage or distribution capacity). How will the proposed plant meet ultimate build-out needs.

VIII. Ozone Treatment System Details

Provide a written description and specifications of the proposed treatment plant. Include engineering drawings with appropriate labels.

1. Feed Gas Preparation
   a. Identify the type of supply gas (air, pure oxygen, other).
   b. Describe the method of gas drying. What is the seasonal variation in air moisture and can the gas be dried to a maximum dew point of -60C (-76F)?
   c. Describe how feed gas is supplied to the generator (pump, and venturi). Define the operating pressures? (If using a compressor, specify "oil free").
2. Ozone Generation
   a. Identify the type of ozone generator (corona discharge, other). The minimum concentration of ozone in the generator exit gas must not be less than 1 percent (by weight).
   b. Define the ozone production rate (g/hr, lbs/day) and ozone concentration (mg/L, ppm).
   c. Specify a minimum of two generators, each sized to provide 50 percent of peak flow or similar alternative.
   d. Verify that the existing power supply can meet the electrical needs of generators. Are the electrical components safety certified?
   e. Describe the method of generator cooling.
   f. Specify corrosion resistant components in the ozone generator.
   g. Has the specified ozone generator been certified by an independent laboratory? If so, list the certifying agent.

3. Ozone Dissolution / Contact Vessel
    a. Describe the method for introducing ozone into the raw water stream (venturi, pump, diffuser, other). Identify operating parameters of method used (such as pressure differential, counter-current flow, mitigation of precipitate formation).
    b. Identify the necessary contact vessel required to provide contact time. Include sizing calculations. How many minutes are required for the ozone to completely oxidize Fe and Mn at the pH of the system (from pilot plant)? Is contact vessel resistant to corrosion?
    c. Include a pressure/vacuum relief valve on the contact vessel; show that it is piped to a location for safe discharge.
    d. Identify on a drawing controls for cleaning, maintenance and drainage of the contact vessel.
4. Off-gas Destruction Unit
    a. Describe a system which meets safety and air quality standards for treating off-gas from the contact vessel (Washington Industrial Safety and Health Act - WISHA - chapter 296-841 WAC- the maximum permissible exposure is 0.30 ppm for 15 minute exposure). If undissolved ozone gas from the contact vessel is recirculated, demonstrate that the ozone concentration (off-gas) in downstream storage vessels is within standards and that the vessel is not subject to excess corrosion.
5. Piping Materials
    a. Specify pipe material with demonstrated corrosion resistivity (such as low carbon 304L or 316L stainless for ozone service, non-solvent welded UPVC pipe, Teflon valve seats). Identify a replacement schedule if recommended by the manufacturer.
6. Ozone Facility Instrumentation
    a. Pressure gauges and air flow meters to monitor the ozone generation process (such as at discharge of air compressor, inlet to ozone generators, and inlet to ozone destruct unit).
    b. Dew point monitor to measure the moisture of the feed gas.
    c. Ozone monitors (or alternate equivalent) to measure ozone concentration in the feed gas, undissolved gas in the contact vessel, ozone residual prior to filtration, ozone residual post filtration and in the off gas from the destruct unit.
    d. An ambient ozone monitor (or alternate equivalent) in the vicinity of the contact vessel and generator.
    e. Pre- and post-treatment sample taps to measure Fe and Mn.
    f. An emergency electrical shut-down accessible from outside of the treatment building.

7. Ozone Facility Alarms
    a. Dew point shutdown/alarm.
    b. Ozone generator cooling water flow, temperature and power shutdown/alarm.
    c. Ambient ozone concentration shutdown/alarm.

IX. **Filtration Process**

1. Filter Media
    a. Identify the components of the filter media and the manufacturer's name.
    b. Attach a copy of NSF approval.
2. Filter Rate
    a. Specify the maximum flow rate to be treated in gpm (attach pump curve).
    b. Identify the manufacturer's recommended treatment unit application rate in gpm/sq.ft? (must be less than 5 gpm/sq.ft).
    c. What is the area of treatment unit(s) proposed in (sq.ft)?
    d. What is the actual application rate (max flow / area) in gpm/sq.ft? Verify that the actual application rate < recommended?
    e. Verify that the system hydraulics are adequate for the proposed filtration.
3. Backwashing Requirements
    a. Describe a backwash cycle including backwash initiation (head loss, timer), backwash rate, frequency, length of backwash, quantity of wastewater, and disposal of wastewater.
    b. Identify the manufacturer's recommended backwash application rate in gpm/sq.ft. (must be greater than 12 gpm/sq.ft). Is the actual backwash rate > recommended?
    c. Identify the backwash pump pressure in psi. Attach pump curve. Verify that system hydraulics are adequate for the proposed backwash.
    d. Provide documentation showing that the Department of Ecology was contacted and that the method of waste disposal is acceptable to them and local authorities.
    e. Verify that no cross connection exists between the backwash source water and the wastewater.

X. **System Hydraulics**

1. Describe the source-pumping configuration (pumps directly to storage or to both storage and distribution).
2. Define the current installed source pumping capacity in gpm.

3. Verify that the installed pumping capacity is adequate to meet current design standards with the proposed treatment on line. Discuss all components of the total pumping head (well pump lift, system elevation difference, treatment plant head loss, system head losses, and residual pressure).

XI. Operations and Maintenance

Prepare an O&M manual section, which includes:

1. Identify maintenance personnel and operators.
2. Outline routine inspection and maintenance—daily, weekly, monthly, annually.
3. Identify major equipment components and their manufacturers.
4. Identify a record keeping system to track treatment system performance.
5. Safety reference WISHA, which establishes permissible levels of airborne contamination (chapter 296-841 WAC).
    a. Provide the manufacturer's Material Safety Data Sheet for ozone. Post a copy of the data sheet in an obvious place in the treatment house.
    b. Provide a summary of the health effect of exposure to ozone. Post a copy of these health effects in an obvious place in the treatment house.
    c. Identify first aid procedures related to ozone exposure.
    d. If unsafe ozone gas is present, define a procedure for exhausting the building and system shutdown (for example, familiarization with ambient ozone monitor function and procedures, or other). How is building access determined to be safe?
6. Disinfection byproduct monitoring plan

Reverse Osmosis for Desalination of Seawater or Brackish Water Issues/Design Review Requirements Checklist

Permitting (verify with local, state, and federal agencies)

- ☐ Water Right Permit (contact the Department of Ecology for current position)
- ☐ Shorelines Permit (county)
- ☐ Building Permits (county)
- ☐ Discharge Permit/NPDES (Department of Ecology)
- ☐ Washington Department of Fish and Wildlife
- ☐ Washington Department of Natural Resources (Aquatic)
- ☐ U.S. Fish and Wildlife
- ☐ U.S. Army Corps of Engineers (Joint Aquatic Resource Permit Application–Section 404 or section 10 permit)
- ☐ U.S. Coast Guard (Bridge or Private Aids to Navigation-PAN)

Source Approval

- ☐ Declaration of Covenant (brackish well or beach well)
- ☐ Intake location:
    a. Shallow well/infiltration gallery should be > 200 feet from any source of contamination(septic drainfield, fuel storage, chemical storage, waste discharge)
    b. Direct seawater intake should be located to consider ease of maintenance, protection from damage (for example, by boat anchors), potential for contamination by fuel spill and sewage discharge.
    c. Depth of intake and affect on TTHM formation and salinity

Pilot Study

- ☐ Purpose: determine if treatment effective; establish recovery rate, pretreatment requirements, operational requirements and costs; predict fouling characteristics of feed water and predict TTHM formation. A pilot study may not be necessary if other plants with the same raw water quality are operating near the proposed project (contact the appropriate DOH regional office to discuss). If a pilot study will not be done, the operator should visit similar plants to gain an understanding of the complexity of the treatment process.

Project Report

- ☐ Treated water design criteria (total dissolved solids (TDS) goal)
- ☐ Corrosive nature of RO permeate
- ☐ Raw water quality, including temperature
- ☐ Treated water quality (from pilot plant study or analogous system)
- ☐ Intake design, including provisions to discourage clogging by mussels (for example, alternating intakes or over sizing intake pipe)
- ☐ Membrane type (cellulose acetate, polyamide/composite)
- ☐ Membrane configuration (tubular, spiral wound, hollow fine fiber)
- ☐ Membrane characteristics (TDS range)
- ☐ Pretreatment requirements (for example, turbidity reduction, Fe/Mn removal, anti-scale stabilization, microbial control, chlorine removal, dissolved solids reduction, pH adjustment, hardness reduction); two treatment trains minimum
- ☐ Useful life of membrane/expected membrane replacement schedule
- ☐ Expected recovery rate (percent)
- ☐ Corrosion control
- ☐ Other post treatment requirements: degasification for CO_2/H_2S removal; disinfection - 4-log viral disinfection meeting the requirements of WAC 246-290-451 must be provided
- ☐ Treatment unit sizing (peak day demand with multiple units for reliability)
- ☐ Description of instrumentation/controls, including alarms and telemetry for remote operation, and provisions for protecting instrumentation and electrical components from corrosion
- ☐ Pump sizing (including manufacturer's performance curves)
- ☐ Equalizing storage for efficient operation of high pressure pumps
- ☐ Waste disposal (must be acceptable to the Department of Ecology)
- ☐ Spill containment for generator fuel if applicable (110 percent of fuel storage tank volume)
- ☐ Noise abatement
- ☐ Testing and certification procedures for startup

Operations and Maintenance Manual

- ☐ Routine O&M
- ☐ Procedures for chemical addition/ determining dosages
- ☐ Plant startup/shutdown procedures
- ☐ Water quality testing for process control/regulatory purposes
- ☐ Membrane cleaning/rejuvenation/replacement procedures
- ☐ Spare parts/chemicals/supplies to be kept on hand
- ☐ Operator certification requirements (minimum WTPO2)/availability of qualified operators)
- ☐ Recordkeeping
- ☐ Copies of monthly report forms (contact DOH for most current reporting format)

Plans/Specifications

- ☐ All components, including membranes are ANSI/NSF Standard 61 certified
- ☐ All chemical used within their ANSI/NSF Standard 60 approved doses
- ☐ Use of non-corrosive materials (stainless steel, PVC, fiberglass) throughout the treatment plant
- ☐ Label taps with chlorinated water, provide supply tank with unchlorinated water