Design Guidelines for Rural Residential Community Water Systems

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FOREWORD

These guidelines cover the design of new waterworks systems or extensions and replacement works to existing systems providing water service generally for housing in rural areas. They have specific application for water utilities regulated under the ***Water Utilities Act*** and ***Utilities Commission Act***, and may be applicable to rural residential water systems owned and operated by local governments and other entities.

The jurisdictions regulating water systems in British Columbia may be summarized as follows:

Ministry of Forests, Lands, Natural Resource Operations and Rural Development - Water Management Branch:

Responsible for licensing and regulating the provincial water resource and administering Water User Communities under the Water Act.

Responsible for regulating private water utilities under the Water Utilities Act and Utilities Commission Act.

Ministry of Health – Health Authorities (6):

Responsible for health aspects of water supply under the Drinking Water Protection Act. Approve system designs, issue Construction Permits and Operating Permits for community water systems.

Ministry of Community, Sport and Cultural Development – Local Government Dept:

Governs the affairs and general administration of local governments under a variety of legislation, including local governments as public water supply agencies (Local Government Act, Community Charter).

Ministry of Transportation and Infrastructure:

Responsible for approvals for highway crossings of pipelines, pipelines within provincial road rights-of-ways, and subdivision approval outside of municipal jurisdiction.

WorkSafe BC - Workers Compensation Board:

Responsible for construction and operation safety practices; Workers Compensation Act.

Local Governments:

Where Regional Districts, Municipalities or Improvement Districts own and operate public water supply systems, they are responsible for design and approvals within their jurisdiction based on various bylaws. Approvals and permits by the provincial authorities are still required where applicable.

Regional Districts and Municipalities are also responsible for land use planning, building permitting and construction inspection services within their jurisdiction.

Municipalities have the subdivision approval authority within their jurisdiction.

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1. GENERAL DESIGN CRITERIA

Rural residential community water systems should have the capacity to provide the following services to its customers:

1. Accommodating domestic (indoor) water demand
2. Accommodating irrigation (outdoor) water demand
3. Firefighting provisions

The following sections of these guidelines outline the minimum requirements for these three demands.

Rural residential community water systems should be designed on the basis of long term planning considerations. Remote areas today may not be so remote 10 or 20 years from now. Therefore basic service infrastructure such as water infrastructure should be designed and constructed to allow for future system expansions and should be compatible with standards by local governments to facilitate future ownership transfers and/or system consolidations. The quality of housing and expectations of service in modern rural subdivisions is comparable to that found in municipalities. Consequently, the water systems should be designed and constructed to a standard that is equivalent to municipal water systems.

While these guidelines document the minimum requirements for rural residential community water systems in B.C., it is recommended that the design engineer also considers local government design standards to ensure compatibility.

As a general rule, rural residential community water systems should be designed and constructed with a focus on simplified operation and maintenance procedures. Most rural water authorities are remotely located and are operated and maintained by part time staff. Delivery times for parts and labour are often lengthy, and frequent and long power outages are to be expected. Hence gravity systems fed from elevated reservoirs are to be preferred if topography allows. A reasonable amount of automation and remote monitoring should be system inherent to minimize operating labour and downtimes.

Each water system design (new construction or alteration) requires at least the approval of the Local Health Authority under Section 7 of the Drinking Water Protection Act. Additional approvals such as a Certificate of Public Convenience and Necessity (CPCN) and approvals by other provincial and/or local government authorities may be required.

2. SOURCE OF SUPPLY

The design engineer must prove that an adequate quantity of water will be available and reliable to meet all applicable demands.

2.1 Surface Water

2.1.1 Lake Sources

For projects involving a lake as water supply source, a water licence must be obtained from the regional office of the B.C. Ministry of Forests, Lands, Natural Resource Operations and Rural Development, Water Management Branch. Water licence application forms are provided online and should be submitted to FrontCounter BC. For source supply from a lake larger than 10 ha in size, the annual licensed quantity must be sufficient to cover the annual average water demand of the proposed development. For source supply from smaller lakes and ponds see Section 2.1.2.

2.1.2 Streams, Springs or Small Lake Sources

A water licence must be obtained from the regional office of the B.C. Ministry of Forests, Lands, Natural Resource Operations and Rural Development, Water Management Branch. Water licence application forms are provided online and should be submitted to FrontCounter BC. The daily licensed quantity must be sufficient to cover the Maximum Day Demand (MDD) of the proposed development.

A hydrology study by a professional hydrologist may be required to confirm the availability of sufficient water.

The reliable yield of the source, after the flow has been regulated by any seasonal balancing storage, should be adequate to supply the Maximum Day Demand (MDD) during moderate drought conditions. Moderate drought is defined as a low flow or water level condition with a return period of not less than 25 years.

2.2 Groundwater

Wells must be designed, located, constructed, tested and disinfected in general accordance with the "Groundwater Protection Regulation" and under the supervision of a qualified professional hydrogeologist or engineer. Wells must be protected from possible sources of contamination with respect to land use adjacent to the wells and the recharge area of the wells.

The total developed groundwater capacity or dependable yield of well(s) must equal or exceed the Maximum Day Demand. The groundwater source(s) should be capable of sustaining this rate of flow continuously for 100 days without recharge by precipitation and without utilizing more than the allowable portion of the available drawdown below the lowest seasonal static groundwater table. The standard method for rating well capacities for utilities is the B.C. Method as described in Appendix 5: “Guidelines for Groundwater Reports and Well Testing in Support of a CPCN” from the “Guide to Applying for a Certificate of Public Convenience and Necessity”.

2.3 Water Quality

All potable water systems regulated by the Regional Health Authorities are required to meet the provincial Drinking Water Protection Regulations under the Drinking Water Protection Act, and shall meet or exceed Health Canada’s Guidelines for Canadian Drinking Water Quality.

In general, these standards require that water supplies for drinking, culinary and other domestic uses be free of pathogenic organisms and their indicators, and free of deleterious chemical substances including radioactive materials. In addition, the water should not have an objectionable colour, odour or taste and should be neither unduly corrosive nor unduly encrusting.

Depending on the proximity of the proposed groundwater source to surface water, investigations for groundwater under the direct influence of surface water (GUDI) may be required.

Details on minimum treatment standards are discussed in Section 4.9.

3. DEMAND CALCULATIONS

On existing systems the water demand should be preferably established from reliable water consumption records such as metering data and pumping records. When reliable records are not available or the project is a new water system, the design engineer shall calculate the critical demands based on the following methodology. Deviations from this methodology may be acceptable if properly justified and explained.

The following basic demand parameters are generally considered for a water system design:

a) Average Day Demand (ADD) – to verify source capacity in form of licence limitations on large lake sources; to derive peak demands from metering data;

b) Maximum Day Demand (MDD) = PF_1 x ADD (a general approximation) – a critical design parameter for sizing reservoirs, pumps and treatment works between source and balancing storage (see Section 3.1 for required MDD calculation methodology);

c) Peak Hour Demand (PHD) = PF_2 x ADD – a critical design parameter for sizing pipes, pumps and treatment works between balancing storage and customers.

d) Fire Flow Demand – calculated based on the Fire Underwriters Survey (FUS) – *Water Supply For Public Fire Protection – A Guide to Recommended Practice*; a critical design parameter for determining maximum network flows, verifying minimum system pressures, sizing pipes/pumps/treatment works between fire storage and customers/fire hydrants.

Table 1: Peaking Factors for Design Parameters

	Peaking Factors	
	PF_1	**PF_2**
> 5,000 Capita	2.0	3.8
< 5,000 Capita	2.5	4
Arid Areas (see Appendix A)	2.5	5

3.1 Maximum Day Demand (MDD)

By definition, Maximum Day Demand is the single highest total 24 hour daily water consumption occurring over a one year period. Depending on the type of development, the MDD is comprised of a number of subcomponents.

For a typical residential subdivision the MDD consists of the following demand components:

MDD = Indoor Demand + Water Loss Allowance + Irrigation Demand

3.1.1 Indoor Demand

MDD for Indoor Demand shall be based on a water use rate of 230 L/capita/day with the following typical occupancy rates:

a) 3.5 persons per single detached dwelling and duplexes;

b) 2.5 persons per multifamily dwelling;

c) 4 persons per recreational property on lakes, golf courses and other recreational destinations.

3.1.2 Water Loss Allowance

The following approach, in accordance with the International Water Association (IWA) and the American Water Works Association (AWWA M36), to quantify water losses is based on physical system parameters including length of mains, number of service connections and average operating pressure.

$$Water\ Loss\ (m^3/day) = 5 \times \left(0.4704 \times L_m + 0.0303 \times N_c + 0.8 \times L_c\right) \times \left(\frac{P}{49.26}\right)^{1.5}$$

Where:

L_m = mains length (km)
N_c = # of service connections
L_c = total length of service connections (km)
P = average system pressure (meters water column)

3.1.3 Irrigation Demand

The irrigation demand is dependent on a number of parameters such as evapotranspiration, type of crop, size of area, soil types and irrigation efficiency. British Columbia can be subdivided into 6 main climatic zones according to specific evapotranspiration rates. Appendix A features these 6 zones and the corresponding evapotranspiration rates whereas an evapotranspiration rate of 2 mm/day is recommended for the Northern/Wet Coastal areas.

Based on the evapotranspiration rate and assuming grass as the typically irrigated crop in residential subdivisions, the irrigation rate can be calculated as follows:

$$IrrigationRate\ (m^3/ha/day) = \left(\frac{Et \times Crop\,Coefficient \times Allowable\,Stress}{Irigation\ \ Efficiency}\right) \times 10\ \left(\frac{m^3/ha}{mm}\right)$$

Where:

$Et = Evapotranspiration\,rate\ \ (mm/day)$

$Crop\,Coefficient = 1\ for\,turf$

$Allowable\,Stress = 0.7\,(Default\ \ for\,turf\ \ grass\,in\,B.C.conditions)$

$Irrigation\,Efficiency\ \ (Percent/100) = See\ below$

Irrigation efficiency is affected by two main factors:

1) The effectiveness of the irrigation system to transfer water to the roots of a crop;

2) The irrigation discipline by water system customers which is influenced by whether water system connections are metered or un-metered.

All new water systems must provide metering to all customers. Consequently, for new and properly designed sprinkler systems in a metered water system, an irrigation efficiency of 70% (use 0.7 in equation above) is used. For existing non-standard irrigation systems and/or un-metered water systems an irrigation efficiency of 50% (use 0.5 in equation above) is used.

Based on the aforementioned equation and assumptions, the peak irrigation requirements can be obtained from Table 2:

Table 2: Peak Irrigation Requirements

Climate Zone	Evapotranspiration Rate Et (mm/day)	Metered Irrigation Rate 70% Efficiency (m^3/ha/day)	Un-Metered Irrigation Rate 50% Efficiency (m^3/ha/day)
Northern / Wet Coastal	2	20	28
Temperate 1	4	40	56
Temperate 2	5	50	70
Intermediate	6	60	84
Arid 1	7	70	98
Arid 2	8	80	112

The areas to be irrigated (ha) should be calculated from cadastral map data and/or average physical measurements wherever possible. In absence of proper data and tools, the irrigation areas should be obtained with the following methodology in Table 3:

Table 3: Typical Irrigation Areas

Land Use	% Irrigated Area / Irrigated Area
Low Density Residential (up to 1,600 m^2/lot)	50%
Low Density Residential (> 1,600 m^2/lot)	800 m^2
Multifamily Residential	40%

3.1.4 Water Conservation Incentives

Water utilities should encourage water conservation whenever and wherever possible.

Indoor water usage can be reduced by installing low flow fixtures and appliances. The installation of such low flow fixtures and appliances are outside the control of a water utility and can only be governed through bylaws by strata corporations or local governments. The indoor usage, as per Section 3.1.1, takes into account a typical application of standard low flow fixtures and appliances in modern subdivisions. A reduction of this indoor demand must be justified by the design engineer on the basis of advanced and enforceable indoor usage conservation measures.

A reduction of the applicable water loss allowance can be achieved by designing and adhering to a pressure management strategy in the water system.

Most tangible water conservation can be achieved by reducing irrigation demands. While sprinkling bylaws/restrictions are very common with water utilities, the results of such vary significantly and therefore do not warrant a reduction of the irrigation demand calculated as per Section 3.1.3. Measurable reductions of the irrigation demand can be achieved by limiting the irrigable area by means of registering restrictive covenants or reducing lot sizes. A number of B.C. municipalities have adopted topsoil bylaws to preserve and enhance existing topsoil thickness within new developments. An absorbent topsoil layer requires less irrigation, stays green longer during a drought and contributes to sustainability of water supply. Typically, a 30 cm topsoil layer maximizes the soil's water storage capacity, thus resulting in a decrease in the number of irrigation days required per week. A 10% reduction in lawn and garden irrigation can be applied to the calculations in Section 3.1.3 for developments that follow the requirements of an existing topsoil bylaw.

3.2 Non-Residential Water Demands

For non-residential water demands, for instance for commercial and/or institutional developments, metering records or, in lack of that, conservative consumption estimates need to be utilized to derive peak demands. These peak demands from non-residential developments are then superimposed upon residential peak demands in order to determine the appropriate design parameter such as MDD or PHD.

Fire flow demands should be calculated based on the latest version of the FUS guidelines to ensure that fire insurance coverage is applicable for the water system service area. Sufficient reservoir storage must be provided to deliver the calculated fire flows for the critical fire flow time period.

3.3 Water Demands for Recreational Resorts

Recreational resorts typically incorporate a water utility providing water service to a number of properties and facilities such as hotels, restaurants, multi-family town homes, condominiums, chalets, single family residences, bed & breakfasts, employee housings, day use facilities, maintenance buildings etc. They may also provide water for irrigation purposes.

For Ski and Mountain Resorts the critical peak water demand period comprises typically the two weeks over the winter holiday season. Maximum Day Demands should be considered for at least this entire period (14 consecutive days) and at 100% occupancy rate. Due to the timing of the peak demand period, the MDD is calculated without irrigation provisions. However, water demands for snow making may be applicable.

Golf and other summer use resorts differ from mainly winter use resorts in that the peak demand period typically falls into the summer season. Therefore irrigation demands for golf courses, park facilities and other irrigable areas need to be superimposed upon indoor demands to derive design parameters such as MDD and PHD. Irrigation demands for golf courses should be determined by a qualified golf course designer. The use of reclaimed water complying with all applicable sewage regulations and health standards may be applied towards irrigation demands for golf courses and similar facilities.

Indoor water demand for recreational resorts should be calculated and recorded on the basis of Bed Units (BU). The Maximum Day Demand (MDD) criterion for indoor usage is 230 L/day/BU. For a detailed calculation of Bed Units, designers should refer to the Ministry of Forests, Lands, Natural Resource Operations and Rural Development, Tourism and Resort Operations "All Season Resort Guidelines".

Chapter II: Mountain Resorts, of the All Season Resort Guidelines [1] defines BU as follows:

"A bed unit is defined as the accommodation required for one person to stay overnight. Bed units can be publicly available on a night-by-night basis and/or privately available on a permanent basis for second home, resort residential and employee use."

As an example: Typically, single family units with 3 bedrooms are assigned 6 bed units; multifamily with 2 bedrooms are assigned 4 bed units; and hotel rooms with 1 bedroom are assigned 2 bed units each.

Table 4 from the same guidelines demonstrates the possible range of bed unit numbers for various accommodation types and different sizes.

Table 4: Bed Unit Model [1]

Form of Accommodation	Unit Size (m^2)	Number of Bed Units
Residential Accommodation		
- Single Family Unit	100 - 450	4 to 8
- Multiple Family Unit	0 – 55	2
	55 – 100	3
	100 – 350	4 to 6
- Duplex Unit	100 – 450	4 to 8 each side
Commercial Accommodation		
- Guest Rooms	0 – 55	2
	55 – 100	3
	100 – 200	4 to 6
- Tourist Pension	n/a	10 to 20
- Bed and Breakfast	n/a	6 to 10
- Campground	n/a	2 to 4 a site
- Dorm/Hostel Bed	10	0.5

4. DESIGN OF WATER SYSTEM COMPONENTS

4.1 General Layout Considerations

A simple water system layout should be achieved to minimize operational and maintenance procedures and system replacement costs. Where practical, water systems should be planned to facilitate emergency exchange of water between, and possible future integration with neighbouring community water systems.

Where ever feasible, all the utility owned water system components should be installed within public rights of way, existing or planned. Typically, utility owned and operated works terminate at, and include, a curb stop, drain valve and valve box located adjacent to the private property line, with the exception of a water meter which may be installed on the private property.

Utility owned water system components to be located on private lands should be within easements or statutory rights of way registered in favour of the utility in perpetuity. The minimum width of a watermain easement/right of way is 6.0 m.

Restrictive covenants on use of land may be required to protect a utility's source of supply or other works, or may be required to restrict building elevations to ensure minimum pressure requirements are met.

Structures and buried facilities should be located within parcels of land and easements in such a way that there is ample space for access, maintenance and replacement of works.

Structures and facilities should be located within parcels of land and easements that enable potential future expansion thereof.

4.2 Intakes and Head Works

Intake and head works in and near streams and lakes should be designed to optimize water quality, minimize maintenance and adverse environmental impacts and not obstruct the passage of vessels in navigable waters. To limit the disturbance to the aquatic environment, intakes should be sized for the ultimate capacity of the water system at build-out. The capacity of the intake and head works should be the MDD anticipated for the next 50 years.

For measuring and recording the extracted water volumes, each intake must be equipped with a piped flow meter in a suitable location as close as possible to the point of extraction. The flow meter should have a totalizing function and should be installed in either a frost protected above-ground enclosure, or be located within an accessible underground meter chamber.

4.2.1 Intake Screens

Intake screens must be designed to meet requirements as set by the federal Department of Fisheries and Oceans in the *Freshwater Intake End-of-Pipe Fish Screen Guideline.* Screen design should also facilitate easy cleaning, preferably self-cleaning.

Stream intakes should be sited in a stable reach of the channel, where erosion or deposition will not endanger the works and in such a way that the natural regime of the stream will not be upset.

4.2.2 Intake Towers

Intake towers should be located as close to shore as possible but at a minimum water depth of 3.0 m. The standard cross section of the tower should be circular or oval whereas in streams the major axis of the oval must be parallel to the flow direction. The top of the tower and the access bridge to the tower should be minimum 1.5 m above the highest water level. Intake towers are to be constructed with reinforced concrete. Intake ports should be gated and provided at various depths with the lowest ports approximately 0.6 m above the bottom and then in 3.0 – 4.5 m vertical intervals. If no screens are installed downstream from the tower, the ports should be provided with intake screens. At a minimum bar screens of 13 – 19 mm steel bars with 5 cm spacing should be provided.

4.2.3 Pipe Intakes

Pipe intakes should reach to water depths that provide safe water supply and adequate water quality even during extreme water level fluctuations. The designer should consider factors such as currents, runoff and sediment flows, typical algae and plankton bloom layers and water stratifications and water temperature layering when designing a pipe intake. The orifice of the intake should be 1.0 m above the lake/stream bottom. If the total water depth is less than 3.0 m a buried intake crib (0.5 – 1.0 m below stream/lake bottom) must be designed and constructed. The crib structure must be built with reinforced concrete and all sides be protected with riprap. Crib ports must be sized to provide a maximum velocity of 0.08 to 0.15 m/s. The intake pipe orifice inside the crib should be bell-mouthed and be equipped with an antivortex plate.

4.2.4 Intake Pipes/Conduits

The intake pipe or conduit must be capable of providing a minimum flow velocity of 1.0 m/s to minimize the accumulation of sediments. To avoid air locks, the pipe or conduit must provide a continuous grade (rising or falling). Intake pipes or conduits crossing streams or lakes can be installed above the stream/lake bottom by means of anchoring the pipes or conduits adequately to the bottom after being floated in place, or they can be installed underground with minimum of 1.0 m cover over the top of the crown. To provide additional ballast over top of an underwater pipe/conduit trench, 2.5 m^3 crushed rock should be placed overtop each linear meter of pipe/conduit.

4.2.5 Infiltration Galleries

Infiltration galleries may be used to indirectly extract water from a stream, spring or a lake if soil conditions are suitable (sand, gravel). Infiltration galleries are permeable horizontal or inclined conduits/pipes into which water can infiltrate from an overlying or adjacent source. They are constructed below the water table in an area where there is sufficient recharge to offset the pumping rate, and where the permeability of the natural soils is sufficient to transmit this quantity of water to the gallery under the existing head conditions. One advantage of this type of intake is the occurring pretreatment during the ground passage of the raw water. The galleries should consist of perforated or slotted plastic, stainless steel or concrete pipes installed horizontally (minimum grade 500:1) in depths of about 4.0 to 5.0 m below the bottom of streams or lakes. The total orifice area should not exceed 18% to 20% of the total pipe wall area. The orifices should be sized for an entrance flow velocity of 0.3 m/min or less, and be adequate for the selected filter material gradation surrounding the gallery pipe/conduit in order to prevent sand from entering the piping system. Infiltration galleries should have provisions for back-flushing.

Intake and head works should be protected against persons and domestic pollution, industrial or other harmful wastes or runoff and should be reasonably accessible in all seasons. They should also be protected from the accumulation of ice.

4.3 Wells

4.3.1 General

The following section outlines the minimum design requirements and considerations for public supply wells in British Columbia. For additional information, requirements and standard practices for well construction, installation/alignment tolerances, materials, well development and performance testing, the design engineer should refer to the B.C. Groundwater Protection Regulation, the AWWA Standard A100-06 and AWWA Manual M21. In case of conflicting requirements, the B.C. Groundwater Protection Regulation requirements shall apply.

The successful completion of a well is typically accomplished in four project phases as follows:

<u>Phase 1 – Planning</u>

Comprehensive planning is crucial for the successful completion of a public supply well. Planning should be led and or reviewed by an experienced geoscientist or groundwater engineer with local groundwater knowledge. The goal of the planning process is to indentify aquifers (water-bearing formations) that permit extraction of sufficient quantity at acceptable quality. Planning also assists the proponent with developing the water source in an economical fashion and protecting it over the long-term.

A variety of approaches can be used to obtain information during the planning process. Geologic and groundwater-specific information is available from local, provincial and federal agencies. It is often useful to discuss a proposed well project with local drilling and pump contractors as they have intimate knowledge about local aquifers. Field investigations include test drilling and sometimes remote methods can be useful (e.g. seismic, electrical resistivity and ground penetrating radar surveys). One or more test wells may be required to identify a suitable production well site.

Well construction and infrastructure requirements should be considered from the start. Specific drilling techniques may be required in some aquifers and/or to prevent subsidence. Early consideration of well casing diameter requirements and construction materials is recommended. Pump type (submersible or line-shaft), pump bowl diameter (optimum and minimum) and wellhead completion (pitless or surface) are also important considerations.

Planning must also identify potential conflicts with existing users of the same (or interconnected) aquifers along with possible mitigation options. The operation of a new well must not compromise water supplies of existing users or nearby ecosystems. Proponents must be aware that aquifers are variously connected to surface water(s), which can lead to associated impacts and greatly complicate approvals.

The best way to forecast potential impacts of a new well is to gain pre-pumping baseline information by installing one or more monitoring wells. Baseline data provides the information required to support or reject claims when disputes arise. Monitoring and assessing actual impacts requires monitoring wells.

Planning for a well involves obtaining various permits and approvals **prior to drilling**. **As a minimum, new public supply wells in B.C. require "Source Water Approval", a "Construction Permit" and an "Operating Permit" issued by the local Public Health Authority.**

Provincial and federal regulations apply to discharge from drilling operations and pumping tests. Local government may have additional requirements above and beyond current health and environmental regulations. It is the responsibility of the proponent to identify all required approvals and permits. Inadequate planning may result in rejection of a new well and (in some cases) fines may be assessed due to inappropriate discharge.

<u>Phase 2 – Well Drilling</u>

Well drilling must be completed by (or under the direct supervision of) a Qualified Well Driller (QWD) registered in British Columbia. The QWD will work in conjunction with (or be supervised by) a Professional Geoscientist or Engineer registered in British Columbia. Drill cuttings should be collected at regular intervals to determine the depth, thickness and characteristics of aquifers and aquitards (confining layers). It is recommended to take water samples during the drilling process and analyze the samples for water quality parameters in a lab. If those preliminary water samples suggest unsuitable water quality of the aquifer then it may be more economical to drill in a new location rather than completing the well.

The majority of wells in BC are drilled using air-rotary rigs but cable tool rigs are still in use and may be preferable in some cases. Care must be taken when constructing production wells using a different drilling method than were used to advance test wells.

Phase 3 – Well Screens, Liners, Installation and Development

All wells completed in unconsolidated formations (i.e. loose sand and gravel) must be constructed with a screen to produce the best water quality possible and reduce the potential for sand production. Bedrock wells must be lined.

Well screen selection can be informal or it can be designed by a professional (an engineered screen). Informal selection is typically completed in the field by a drilling contractor based on their experience with the aquifer and nature of the cuttings. This is a good approach, however some aquifers can prove challenging to screen and the involvement of a professional is recommended. Engineered screens require grain-size analysis of several grab samples collected from the water-bearing formation(s). Well screen selection is best accomplished by the professional and contractor working as a team.

Well screens are commonly installed utilizing the "pull-back" method where casing is withdrawn to expose the telescopic screen directly against the aquifer formation. Single-string screen completions which integrate the production casing with pipe-size screen are typically used in artificially-packed wells. Considerations should be given to a suitable well diameter because artificially-packed screens reduce the effective well bore diameter by about 100 mm.

Adequate development of the well screen is necessary to remove finer particles (such as fine sand, silt and sometimes clay) from the aquifer formation adjacent to the screen. Removal of these finer particles allows groundwater from the aquifer to flow freely into the well bore and creates a filter around the screen. Well development techniques include bailing, pumping, air-lifting, surging, rawhiding and jetting. It is useful for the contractor and professional to work as a team to optimize well development.

It should be noted that Health Authority approvals are based on the quality of the water sample collected at the end of the well test (pumping test described below). It is highly recommended that turbidity in the well discharge at the end of the development is as close as possible to meeting the Guidelines for Canadian Drinking Water Quality.

Phase 4 – Pumping Test

A pumping test is required for each new production well. The objective of the test is to document the actual performance of the well (yield and water quality) and ideally, stress it beyond the desired capacity. It is possible to estimate long-term well yields from pumping tests of a reasonable duration.

The duration of a pumping test will depend upon the sensitivity of aquifer development, rate of water level drawdown stabilization in the well, observed turbidity and impact assessment objectives. The minimum duration of pumping tests with a constant pumping rate is 24 hours for wells in unconsolidated formations and 72 hours for wells in bedrock. Pumping tests should be designed and directly supervised by the geoscientist or qualified groundwater engineer. To determine the appropriate constant pumping rate for the pumping test of a well, a step test should precede the actual pumping test period.

The accepted "specific capacity" method for evaluating long-term well yield is provided in Appendix 5 to the document "Guide to Applying for a Certificate of Public Convenience and Necessity", Ministry of Forest, Lands and Natural Resource Operations. The Q_{20} method is not an acceptable method to estimate the long-term yield of a well in B.C.

A well cannot be rated higher than the pumping rate during the pumping test period.

The following sections describe and specify a number of details relevant to the four major well completion project phases.

4.3.2 Well Location

The location of a well is often constrained by available property and ownership. In some cases geology is well enough defined to influence well siting, however, this must be balanced with a local knowledge of land uses that may influence or impact groundwater quality. As described above, test wells are often required to identify a suitable and or optimum production well location. Test wells should be converted into permanent monitoring wells (and measured during testing) or properly abandoned as per provincial regulations.

Production wells must be fully accessible at all times via statutory right of ways written in favour of the utility. Well sites must not be subject to flooding and site grading must direct surface runoff away from the wellhead. Provincial regulations stipulate specific construction details for wellheads. Wells should be located **separate** from pump houses or other enclosures to facilitate access for future well re-development and rehabilitation. Specialized well covers are available for cold climates. Electrical equipment, water treatment and disinfection can be incorporated into an adjacent (or centralized) enclosure. Kiosks in lieu of pump houses are an acceptable alternative in many areas. All wells, pump houses and kiosks must be located within a secure fenced compound to prevent vandalism and unauthorized access.

4.3.3 Well Casing

Permanent well casings must be continuous and watertight. Production wells shall have a minimum casing diameter of 200 mm to allow installation of a nominal 100 mm diameter pump assembly. A minimum 8.2 mm wall thickness is required for 200 mm well casings.

Manufacturing standards for single-ply carbon steel well casing are as follows: ANSI/AWWA C200, API Spec. 5LX, ASTM A53 Grade B, ASTM A139 Grade B and ASTM A778. For larger diameter casings and/or site specific structural requirements refer to AWWA A100-06 and/or a specific design by a qualified engineer or geoscientist.

The casing must extend a minimum distance of 300 mm above finished grade. Consideration should be given to lengthening stick-up if the well is located in an area of heavy snowfall. Top of casing (not including the vented cap) for public supply wells must be at least 600 mm above the 100-year flood level of record. Site protection from erosion may also be required near small streams prone to flooding.

The use of PVC casings is not acceptable for public water supply wells. Non-ferrous alternatives (such as fiberglass) may be considered in specific circumstances by approval of the authorities. Stainless steel in lieu of non-ferrous casings should be considered if corrosion is a concern.

4.3.4 Well Liner

Bedrock wells must be lined using PVC or light-gauge steel casing to prevent collapse of the well over the long-term. A steel liner is recommended for depths greater than 150 m.

4.3.5 Well Screens and Gravel Packs

The well screen interval is dictated by the depth and thickness of water-bearing zones. Screen length should consider the total thickness of the aquifer and the increased efficiency which results from a longer screen. Other factors, including the estimated pumping water level, screen entrance velocity, turbulent flow and the effects of long-term fouling, must be considered. In some cases informal screen designs (described above) are appropriate, however, the majority of public supply wells will require high-efficiency designs to maximize production and minimize long-term operating (including power) costs.

It is generally recommended to avoid drawing the water level into the screen to reduce the potential for scaling, corrosion and increased fouling. However, this is often not possible in shallow or fine to medium sand formations that present low yield. In these cases, the well should be designed by a geoscientist or groundwater engineer specifically for operation in this manner. Design considerations should include blank screen sections and or a sump for installation of the pump with a protective flared cooling shroud. Additional precautions such as a fabricated stainless-steel riser pipe and or pipe-size assembly should be considered. A nearby monitoring well is highly recommended to confirm the aquifer is not being depressurized or dewatered during testing and regular operation. Operating well levels within the screen elevations should only occur during peak demand times and not on a regular basis.

Well screens should be commercially fabricated keystone wire-wound 304 or higher grade stainless steel. Alternate screen designs (i.e. louvered or punched) may be acceptable but it should be recognized that sand and turbidity control can be difficult to achieve without wire-wound designs. Pipe-based wire-wound screens may be required for specialized applications and very deep settings. The following presents wire-wound screen-design recommendations:

- Naturally-developed screens (telescopic or pipe size) should be designed with a slot opening equal to D_{40} to D_{60} (passing) of the aquifer formation. A highly uniform formation (C_u less than 3) may be prone to sanding and should have a conservative slot size relative to the formation grain-size distribution. A well-graded formation (C_u greater than 6) can often support a coarser slot size. High-quality and representative samples are required when designing naturally-developed screens with slot sizes finer than 0.5 mm.
- Artificially-packed screens (traditional or manufactured pre-pack) should be designed with a slot opening equal to D_0 to D_{15} (passing) of the filter material. Packaged and sterilized commercial aggregate is recommended for filter construction owing to its uniformity (carbolite is often used in pre-packed screens). The filter will have a grain-size ideally in the range of 4 to 6 times the D_{15} (passing) of the finest representative sample collected from the formation.

Note: C_u = Coefficient of Uniformity = ratio of the sieve size that will permit passage of 60% of the media by weight to the sieve size that will permit passage of 10% of the media material by weight = D_{60} / D_{10} (passing)

Care must be taken to locate the screen interval within the main portion of the formation to prevent the migration of fines into the screen during development. It is a recommended to not extend the screen within 0.5 m of the aquifer top and bottom. Telescopic screen designs shall allow for at least 1.0 m of overlap and will be sealed against the production casing with an elastomeric seal (neoprene K-packer). A grout seal shall be emplaced above any artificial filter pack (other than pre-packed telescopic screens). The bottom plate and or sump must be constructed of the same material as the screen.

4.3.6 Surface Seal

The BC Ground Water Protection Regulations specify minimum well sealing requirements. This section provides additional recommendations suitable for public supply wells and should be used by contractors and professionals to assure a properly constructed well.

All annular space between the borehole and production casing should be sealed with an appropriate sealant to a minimum depth of 5.0 m. This includes any surface and telescopic casings left in place for various reasons (such as artesian pressure control). The seal must prevent surface water and or contamination from entering the annulus via the surface. The seal should have a minimum 50 mm thickness and must be suitable for the application and the environment. Typically, a Bentonite Grout mixed to 30% solids (by weight) is recommended. Under certain circumstances and upon approval by the engineer or geoscientist, the following materials can be utilized for surface seals:

1) Neat cement as per AWWA A100-06;
2) Neat cement and bentonite mixtures (used with caution as these two compounds compete for hydration).

The grout/sealant must be placed into the annulus from the base of the desired interval to the ground surface. The grout shall be mixed at surface and pumped continuously or as a series of batches. Grout should be pumped until it discharges from the surface at the same solids content as pumped to minimize the potential for washout.

Single-string screen completions require considerable thought and care to properly seal undesired zones which may impact water quality.

Where pitless adaptors are installed or other well excavations occur after the surface seal is placed, the surface seal must be properly repaired during backfilling or the surface seal must extend sufficiently beneath the excavation to achieve the minimum required surface seal depth.

4.3.7 Well Pump and Discharge Piping

Typically, submersible pumps are installed in wells. Vertical-turbine line shaft pumps may be desired to improve efficiency in high-capacity applications. Jet pumps accommodated in above ground pump stations may be acceptable under specific circumstances. The well pump and motor should be sized based on the desired long-term peak pumping rate with some allowance for wear over time and changing lift / hydraulic head requirements (see Section 4.6.2. Electrical cables shall be properly strapped to the drop pipe at regular intervals.

The discharge piping should incorporate at least one check valve, an isolation valve, pressure gauge, flow meter (totalizing) and a sampling spigot. A combination air valve may be required upstream from the check valve with exhaust/relief piping terminating above floor elevation in a downward position with a corrosion resistant screen. Discharge piping should be configured to allow testing of each installed pump with provisions to discharge to waste. The proponent is responsible for ensuring that discharge to waste is authorized by regulatory agencies. The majority of these piping components should be accessible via an above ground pump station building or within an underground valve chamber. If pitless adaptors or units are utilized, at least one check valve should be located within the well casing upstream of the pitless adaptors or units.

4.3.8 Pitless Adaptors and Pitless Units

Pitless adapters or pitless units must be used for wells that are not housed within a building and where the well discharge piping connects directly underground to the water system. The pitless adapters or units should be installed below the local frost penetration depth. Pitless adapters are to be made of materials compatible with the well casing and discharge piping to prevent corrosion. They should be dependable and provide access to the pump for maintenance or repair.

Pitless units are to be fabricated and installed from the point of connection with the well casing and should include a suitable well cap. Pitless units are to be welded or threaded to the original casing below the maximum anticipated frost depth. They should provide an inside diameter suitable to access/remove the pump for maintenance or repair, and to accommodate cables, sounding tubes and other well appurtenances. Pitless units should be of materials compatible to the casing and discharge piping to prevent corrosion. Specialized units may be required to control artesian discharge.

Snappy pitless adaptors or units are not acceptable.

4.3.9 Other Well Appurtenances

Provisions should be made for periodic measurements of water levels in completed wells. Two 25 mm diameter PVC sounding tubes should be installed into each well for redundancy and dedicated use.

4.3.10 Well Disinfection

Upon construction and before connection to a potable water system, the well must be disinfected to remove any bacteriological contamination. A well must also be disinfected after detection of bacteriological contamination. Steps for a standard well disinfection process are outlined below. Procedures for shock disinfection or hard to disinfect wells can be found on the website of the B.C. Ministry of Environment/Water Stewardship Division or in ANSI/AWWA C654.

The standard well disinfection requires a chlorine concentration of 50 to 200 mg/L throughout the water column. Based on the well casing diameter and water depth, the required amount of commercial bleach is calculated and mixed with a suitable volume of water. This concentrated solution is then added to well and should be maintained for at least 12, preferably 24 hours. After this period, the exhausted chlorine solution must be pumped to waste in an environmentally sensitive manner (authorities typically require dechlorination before discharge). It shall not be pumped into the distribution system. Chlorination of the distribution system should be completed as a separate step as per AWWA C651-05.

4.3.11 Well Protection

A key component in protecting community well water supplies is the development and implementation of a well protection plan by the community. A well protection plan contains practical, protective measures to minimize and prevent undesirable impacts from land use activities on the source of water for the community well. Protecting source water through a well protection plan is one of the barriers in the multi-barrier approach to drinking water protection. Experience from elsewhere in Canada, the USA, and Europe shows that preventing contamination of water quality by implementing a well protection plan is the best and most cost-effective way to protect a community's well water supply.

In 2000, the Province of British Columbia, Environment Canada and the British Columbia Ground Water Association jointly published the Well Protection Toolkit. The toolkit is a set of guidelines for the six-step approach on how a community can develop and put into place a well protection plan to prevent contamination of their well water supply. The toolkit contains seven booklets which discusses these six steps and includes an example of how each step is implemented in the fictitious community of Pumphandle, B.C. The toolkit was updated in 2006 to reflect new Ministry names, legislation and websites. The six steps to a well protection plan are as follows:

1) Form a Community Planning Team
2) Define the Well Protection Area
3) Identify Potential Contaminants
4) Develop Management Strategies
5) Develop Contingency Plans
6) Monitor Results and Evaluate the Plan

The complete Well Protection Toolkit can be found on the following B.C. Government website: http://www.env.gov.bc.ca/wsd/plan_protect_sustain/groundwater/wells/well_protection/wellprotect.html

In addition to a well protection plan, there are number of other measures a well designer and/or well owner should consider for keeping a well and aquifer safe. These measures are not limited to the following:

- Ensure the wellhead is graded so that surface water drains away from the well;
- Protect the casing protrusion from physical damage;
- Operate the well in a manner that prevents the intrusion of saltwater of contaminated water into the well or aquifer;
- Do not disturb the wellhead or surface seal or when disturbed repair properly;
- Ensure the pump house is in good repair and kept free of chemicals and other contaminants such as pesticides, fertilizers or gasoline;
- Regularly sample the water quality of the well and disinfect the well if needed.
- Consider intrusion alarm systems on well caps or well enclosures.

4.3.12 Flowing Artesian Wells

The provincial regulatory requirements for controlling flowing artesian wells are outlined in Section 77 of the Water *Act.* If artesian conditions are encountered when constructing or supervising construction of a well, the qualified well driller or qualified professional must ensure the artesian flow is controlled and advise the well owner (and the land owner, if applicable) of the steps taken to do so. If the flow cannot be controlled, the person responsible for drilling the well should advise the B.C. Ministry of Environment's regional hydrogeologist and must comply with any directions given.

A flowing artesian well must have a securely attached cap to provide access to the well, prevent entry of vermin and contaminants, and to prevent flow escaping from the well. A flowing artesian well is considered "under control" when the entire flow is through the production casing to the wellhead and the flow can be stopped or directed indefinitely without leaking on the surface of the ground and with no leakage into any other aquifer penetrated by the well.

Wells with artesian head of pressures less than 3.5 m can usually be controlled with extended casing above the piezometric level and using a 30% bentonite grout for the surface seal. Wells with artesian head of pressures between than 3.5 and 7.0 m require an outer surface casing of minimum 20 cm greater diameter than the final production casing. The outer casing should extend into the confining layer but not penetrate the underlying artesian aquifer. The annulus between outer and inner casing can then be sealed with cement-type grout. For wells with artesian head of pressures in excess of 7.0 m, site specific solutions need to be designed by a well specialist to safely control the flows. This may include one or multiple outer casings achieving a minimum annulus of 15 cm between outer and production casing and high density grouts such as cement/barite mixtures etc.

4.4 Impounding Reservoirs

Impounding reservoirs should be designed to prevent, insofar as it is practicable, deterioration of raw water quality by minimizing contact with organic materials (grass, peat, trees etc.) and avoiding shallow water areas and embankment erosion.

Existing wells which will be inundated require proper abandonment according to the regulations.

The design and construction of dams and spillways requires approvals from the appropriate regulatory authorities. Further approvals and permits are required from regulatory authorities for controlling or altering stream flows or installing structures in fish bearing streams or navigable rivers.

4.5 Transmission and Distribution Pipes

All water transmission and distribution pipes, including service connections, should be sized according to flow demands and pressure requirements. The distribution system should be designed to convey domestic, irrigation and fire flows. Separate piping systems for different purposes such as irrigation, domestic or fire suppression are not acceptable as they incur higher operation and maintenance/replacement costs and pose a significant risk of cross connections.

The minimum pipe cover should be greater than the depth of frost penetration but minimum 1.0 m. Minimum pipe cover at ditch crossings should be 0.6 m. Non-buried pipes should be housed in a heated enclosure or protected from freezing through heat tracing.

Distribution pipes should be looped where practical and the number of dead-ends should be minimized. Where dead-end sections cannot be avoided, they should be designed with means to provide adequate flushing.

All pipes should be adequately restrained from thrust movement via thrust blocks and/or mechanical restraints on all critical points.

4.5.1 System Pressures

The system should be designed on the basis of providing a minimum pressure of 140 kPa at ground level at all points of the system under all conditions of flow, including MDD plus critical fire flow conditions.

The working pressure during Peak Hour Demand (PHD) conditions should ideally be about 400 kPa at the living floor elevations with a minimum system pressure of 280 kPa during these conditions. A utility should also provide system pressures at living floor elevation ranging between minimum 280 kPa and maximum 700 kPa. To reduce the number of pressure zones required and where only a few sites would receive pressures exceeding 700 kPa, individual pressure reducing valves may be allowed in dwellings.

A steady working pressure is desirable. Pressure fluctuations during various flow conditions should not exceed 20% or 100 kPa measured at the curb stop of each service connection.

All waterworks must be designed to withstand the maximum working pressure plus the transient pressure to which it may be subjected.

4.5.2 Pipe Materials

The pipe materials selected for particular applications should be able to withstand, with a margin of safety, all combinations of loading conditions to which they are likely to be exposed.

Water pipes and fittings made of the following materials and meeting the applicable quality standards and specifications set by AWWA are acceptable for buried applications: PVC, HDPE, Ductile Iron and Reinforced Concrete.

Non-buried water pipes may be constructed of rigid materials such as PVC, stainless steel, powder-coated steel, ductile iron or copper meeting the applicable quality standards and specifications set by AWWA.

4.5.3 Friction Factors

Where data are not available from actual field tests, the water pipes should be designed using Hazen-Williams C-factors listed in Table 5 for pipes made of standard materials such as PVC, HDPE and Ductile Iron.

Table 5: Hazen-Williams C-Factors

Diameter - Nominal	C-Factor
150 mm	100
200 – 250 mm	110
300 – 600 mm	120
over 600 mm	130

4.5.4 Pipe Diameters

The minimum diameter of distribution pipes should be 150 mm to enable the system conveyance of fire flows to each fire hydrant location, except within 100 m of a cul-de-sac or other dead end termination such as a body of water, ravine, railway embankment or similar obstruction. A dead end termination would preclude the possibility of future extension, in which case 100 mm diameter may be acceptable.

Pipe diameters should be such that a flushing velocity of 0.8 m/s can be achieved for cleaning and flushing procedures.

The maximum flow velocity at PHD should not exceed 1.5 m/s. The maximum flow velocity during MDD and fire flow conditions should not exceed 3.0 m/s.

4.5.5 Service Pipes

The minimum diameter of service pipes should be 19 mm. Service pipes should be constructed of standard materials such as PVC, HDPE or copper and should conform to the AWWA Standard C800: Underground Service Line Valves and Fittings.

The maximum length of water service lines from the watermain to the property should not exceed 30 m and shall be installed at 90 degrees to the distribution main pipeline.

Each lot should be serviced by only one water service connection/pipe. Each service must be metered. The meter should meet the specification of the local authorities and should be installed in a suitable meter box with meter setter, isolation valves and backflow preventer just outside the property line. Meters and valves must be frost protected.

Where it is necessary to supply a property via a service pipe across an adjacent property, an easement in favour of the property to be served must be obtained. The owner of the property served is responsible for the service pipe within the easement.

4.5.6 Fire Hydrants

Fire hydrants should only be installed on watermains capable of supplying fire flows. Fire hydrants should be dry-barrel type and conform to the latest edition of AWWA Standard C502: Dry-Barrel Fire Hydrants. Fire hydrants should be provided with adequate thrust blocking to prevent movement caused by thrust forces. Hydrant leads must have a minimum diameter of 150 mm and must incorporate a hydrant isolation valve. In areas where the groundwater table will rise above the hydrant drain port, the drain port should be plugged.

The maximum lineal spacing between hydrants should be 150 m for single family land use zones and 100 m for multi-family and commercial zones.

Hydrant access crossings should be provided for hydrant installations adjacent to open ditches.

Fire hydrants should be located minimum 2.0 m from the edge of roads and minimum 3.0 m from obstructions such as trees, hydro poles, lamp posts etc.

Ideally, fire hydrants should be located on low points in the distribution system.

4.5.7 Line Valves

Line valves should be placed throughout the distribution system at each intersection's downstream pipe branch and at maximum linear intervals of 150 m.

All valves should conform to relevant AWWA standards.

Thrust blocking or other restraints should be provided on line valves.

4.5.8 Air Valves

Air valves (air release valves, air vacuum valves, combination air valves) should be located throughout the piping system to avoid air accumulations at high points, prevent negative pressures and facilitate pipeline draining.

All air valves should conform to AWWA Standard C512: Air Release, Air/Vacuum and Combination Air Valves for Waterworks Service.

Air valves should be installed in accessible manholes or chambers.

Automatic air valves should not be used on situations where flooding of the access manhole/chamber may occur.

4.5.9 Blow-Off Assemblies

Blow-off assemblies should be provided at the extremities of terminal pipe sections. Fire hydrants can act as blow-offs on pipes that are capable of conveying fire flows. On smaller pipes, blow-off devices capable of producing a flow velocity of minimum 0.8 m/s should be installed to achieve adequate flushing.

4.5.10 Pressure Reducing Valve Stations

Pressure reducing valves (PRV) are typically located at the border of different pressure zones. The PRVs should be accommodated in a conveniently accessible underground valve chamber outside road traffic lanes and at locations that are not subject to flooding. PRVs should be sized to provide adequate pressure control under all flow conditions. Underground valve chambers shall be designed so that one person can enter the vault for servicing in accordance with Workers Compensation Board (WCB) requirements for "Confined Space Entry".

Typically, PRV stations with fire flows should have a fire line PRV for large flows and a smaller bypass PRV for regular flows. PRVs should incorporate a valve position indicator. Every PRV station should have a valved bypass line. Isolation valves inside the valve chamber should be provided upstream and downstream of each PRV. A downstream surge relief valve should be installed to release pressure in the event of a failure of the PRV. The surge relief valve may be located inside the PRV station or in another suitable location within the distribution system. The surge relief valve should discharge safely to the storm sewer system or other drainage facilities. PRV stations should also be equipped with pressure gauges complete with snubbers and isolation valves to register upstream and downstream pressures, a combination air valve at the station inlet, and drain valves between the isolation valves. Pipe materials should comply with Section 4.5.2. Valve specifications should conform to all relevant AWWA standards. Adequate provisions for equipment removal through couplings or detachable pipe connections are to be provided. Pipe anchorage and supports for thrust, restraint, and bracing of equipment, valves and piping for pressure, transients, and seismic forces are to be provided. Design requirements for underground chambers are specified in Section 4.8.

4.5.11 Pipe Separation Distances

Water pipes (watermains and water service pipes) must maintain a clear horizontal separation distance of 3.0 m minimum from any sanitary or storm sewer pipe. For short distance water services (max. 30.0 m pipe length from water service saddle at the watermain to the house), the horizontal separation between water service pipes and other property service lines (including sanitary and storm sewers) may be reduced to 1.5 m minimum.

At pipe crossings, a minimum clear vertical distance of 0.45 m between water pipes (watermains and water service pipes) and any sanitary or storm sewer pipe must be provided.

Any water pipe should maintain a minimum horizontal distance of 1.5 m and a minimum vertical distance of 0.2 m at crossings to any non-sewer utility infrastructure.

4.6 Pump Stations

As vital components of a water system, pump stations should be located and designed accessible, preferably above ground, protected against service interruptions due to fire, flood, lightning strike, vandalism or other hazards, and adjacent to vehicular access.

All pump stations should be designed to provide 100% system capacity redundancy in order to meet the critical design demands in a situation where any one pump is out of service. This necessitates a minimum of two pumps of equal capacity per pump station.

4.6.1 Pump Station Enclosure

Pump station enclosures/buildings must be in compliance with the B.C. Building Code, the requirements of the Workers Compensation Board (WCB) and all other applicable standards and regulations.

The enclosure for a water pump station should consist of a building structure that is durable under damp conditions, both fire and weather resistant and constructed with outward-opening exit doors. The pump station building is preferably above ground and constructed of concrete blocks. The building floor should be sloped and provided with a floor drain sufficiently designed to keep the station functioning and accessible during emergency spill/leakage situations.

The building should provide adequate space for all installations to enable access and working space for each pump station component. This includes space required to maneuver tools and equipment necessary to perform the entire spectrum of operation and maintenance procedures. Aisle widths of minimum 1.0 m should be maintained (measured with doors and panel doors swung open) for access ways throughout to the exit doors. The vertical clearance of the building interior should be 2.4 m minimum.

Electrical controls and panels should be located away from the wet installations where negative interferences are minimized but visual access can be maintained. In larger stations, electrical controls and panels can be located in a separate dry room or compartments with visual access to the installations through glass windows.

The building should provide adequate lighting throughout. Provisions for adequate heating to prevent freezing are required. Forced ventilation of at least 6 air changes per hour should be installed including make-up air provisions. Ventilation should be automatically controlled via a temperature/humidity sensor or a timer.

Exterior walls below grade must be watertight by means of suitable coatings and membranes, and provisions should be made to keep and direct water away from the walls. Interior walls are to be painted white.

4.6.2 Pumps

The pumps should be designed to satisfy the design demand with allowance for some future loss of efficiency due to wear. The pumps and pump motors should be capable of meeting the design demands without overloading. All pumps should be certified for potable water use.

The pumps should be located accessible from all sides and provisions should be made for convenient removal and replacement (e.g. lifting devices, crane tracks, roof hatches, etc.).

To reduce inrush currents during pump starts, pumps/motors of 7.5 kW or 10 HP or more should be controlled through a soft starter or a variable frequency drive (VFD).

The pumps should be designed for normal operation within +/- 10% of their best efficiency point (BEP) on the impeller specific pump curve. Pump motor power must be adequate for all conditions on the pump curve including run-out condition which should be covered within the common motor service factor of 1.15.

Fire pumps and controls should be in accordance with NFPA-20.

4.6.3 Valves and Piping

The piping of any pump station should be designed to minimize pressure head losses.

Piping materials should be in accordance with Section 4.5.2. Valve specifications should conform to all relevant AWWA standards. Isolation valves should be provided for all equipment and each section of piping which may be isolated should be fitted with a valved pipe drain. Adequate provisions are to be made for equipment removal through couplings or detachable pipe connections. Pipe anchorage and support are to be provided for thrust as well as support, restraint, and bracing of equipment, valves and piping for pressure, transients, and seismic forces.

Air valves (release and/or vacuum) are to be provided as required.

Provision for surge protection should be considered if transient pressures are expected. This can be achieved by provision of either suitable pump controls (soft starters, VFD) and/or surge control/relief valves.

Each pump should have a non-slam check valve on the discharge pipe between pump and pump isolation valve.

4.6.4 Appurtenances

Each discharge pipe between the pump and the pump isolation valve should be fitted with a pressure gauge. Further pressure gauge locations should be at the common discharge header and suction header pipe.

Each pump station should provide a flow meter located on the discharge header pipe. The flow meter should be suitable for the full spectrum of design flows and should feature totalizing and indicating functions as well as output options for data loggers.

4.6.5 Backup Power Supply

Backup power generators are recommended for all pump stations. Permanent standby generators should be controlled by an automatic transfer switch. For mobile and other non-permanent generators, a convenient plug-in and manual transfer switch should be provided.

For water systems or water system parts that are not serviced by gravity from a storage reservoir, dedicated backup power generators must be provided for each pump station or other vital equipment to maintain minimum essential water service, including fire protection.

4.7 Distribution Storage Reservoirs

Distribution storage reservoirs must be designed to meet storage requirements for the following purposes:

1. **Balancing Storage:** to balance the fluctuations in domestic demands and irrigation and allow for reasonable on/off frequencies of the supply pumps;
2. **Fire Storage:** to provide sufficient water for the critical fire flow/duration demands in the system;
3. **Emergency Storage:** to provide water in case of power outages and restriction in source supply.

The total storage should be reliably available, preferably by gravity. Storage reservoirs should be elevated to provide sufficient system pressures under any flow condition (see Section 4.5.1). If elevated storage is not feasible, pumping from ground level storage may be considered, in which case a dedicated backup power supply must be provided. As part of the Design Brief however, the design engineer must prove to the Comptroller of Water Rights that elevated storage is not feasible based on a lifecycle cost analysis.

4.7.1 Balancing Storage

Storage to balance the difference between the instantaneous demands and the average demands should be minimum 25% of the MDD.

For existing systems with available flow data, the required balancing storage can be determined as the maximum value calculated from a mass analysis of daily peak demands.

Hydropneumatic tanks are acceptable for facilitating pump control functions but their volumes cannot be credited against storage requirements.

4.7.2 Fire Storage

The fire storage volumes should be calculated based on the requirements of the local fire protection authority or as minimum standard according to the Fire Underwriters Survey (FUS) guidelines "Water Supply for Public Fire Protection" calculated for the critical property in the system.

Table 6 provides some fire flow examples based on FUS guidelines 1999 for typical residential buildings in a rural setting assuming that contents are non-combustible and buildings are not equipped with sprinklers.

Table 6: FUS Fire Flow Requirements for Various Buildings

House Size (sq. ft)	Construction Type	Exposure distance[1] (m)	Fire Flow (l/minute)	Duration (hours)	Volume required (m^3)
1,300	brick / masonry	> 45	2,000	1	120
1,300	wood frame	> 45	2,900	1.25	218
1,300	wood frame	20	3,200	1.3	250
2,000	wood frame	> 45	3,600	1.4	302
2,000	wood frame	20	4,000	1.5	360
3,000	wood frame	20	4,800	1.7	490

[1]Exposure distance is for a building exposure on 1 side with all other sides assumed as greater than 45 meters away from surrounding buildings

4.7.3 Emergency Storage

Emergency storage provides water during events such as natural disasters, pump power failure, source failure or watermain breaks.

The emergency storage should be calculated as follows:

Emergency Storage = 0.25 x (Balancing Storage + Fire Storage)

4.7.4 Reservoir Design

Storage reservoirs should preferably be buried and reinforced concrete structures consisting of two equal cells. Alternatively, above ground insulated bolted steel reservoirs may be considered if buried concrete structures are not feasible or pressure requirements dictate higher water level elevations.

Reservoir sites should be provided with vehicle access and parking space.

The reservoir structure, including foundation and soil base, must be designed by a registered structural engineer. The structural design must include seismic considerations. An associated geotechnical report must be submitted with the application for a Certificate of Public Convenience and Necessity (CPCN).

Reservoirs must have separate inlet and outlet pipes that facilitate a positive circulation of water within the reservoir. Reservoirs should be provided with overflow pipes of greater flow capacity than the maximum reservoir inflow rate. Overflow pipes must discharge visibly and safely to the environment and should not have a direct connection to any sewer or storm drain pipes. Overflow pipes on above-ground reservoirs should be terminated 500 mm above finished grade and discharge to an engineered drainage inlet structure or a splash plate. A dechlorination chamber at each overflow outlet should be considered. Overflow pipes should also be properly screened.

Reservoir roofs must be watertight and adequately sloped and drained to prevent pooling of rain waters. Downspouts should not enter or pass through the reservoir.

Reservoirs should be properly vented. The vents must be designed to prevent access/contamination by birds, vermin and dust. Gooseneck vents must be screened and should terminate 500 mm above the surrounding surface.

Storage reservoirs should be accessible for inspection, cleaning and maintenance. Access hatches should be sized adequately to conveniently accommodate personnel and equipment access. Access hatches should be sealed, have a locking device and should be operable by one person. Access hatches on reservoir roofs should be elevated 200 mm minimum to prevent drainage water from entering the reservoir through potentially compromised seals.

Reservoir controls should consist of at least the following items:

1. Electronic level control device linked to the supply pump(s); e.g. ultra-sonic or pressure transducer etc.;
2. Secondary level control device for high level alarm and linked to supply pump(s) for pump stop (electronic units or float);
3. Secondary level control device for low level alarm and linked to supply pump(s) for pump start (electronic units or float);
4. Overflow and Low level alarm dialed to pager or cell phone of operator if not linked to a SCADA system.
5. Access alarm

Isolation valves can be located either inside an accessible valve chamber or inside a valve building adjacent to the reservoir, or be buried types with proper valve boxes and a minimum 500 x 500 mm concrete slab around each valve box. Valves should be clearly identified with plates or colour codes to display their purpose and function. Flow or pressure control valves must be located accessible in a valve chamber or building.

Above-ground reservoirs should be esthetically pleasing. The area immediately around the reservoir should be cleared from trees and shrubs to allow for circumferential access for visual inspections. The site of any reservoir structure should be graded in a manner that facilitates site drainage away from the reservoir.

Reservoir sites should be secured by means of fencing. Above-ground reservoirs should be additionally secured against unauthorized access to the ladder/stairs leading to the reservoir top.

4.7.5 Reservoir Disinfection

Completed reservoirs should be cleaned and disinfected in accordance with current AWWA standards. Two or more successive sets of samples, taken at 24 hours intervals, may be required in order to confirm that the water is microbiologically safe before the storage facility can be placed into operation.

4.7.6 Spill Response Plan

A spill response plan should be developed for the utility in the event of a major reservoir spill or catastrophic reservoir failure. The response plan should be tailored to the specific reservoir design and location. The plan should outline which design features are in place or need to be activated for minimizing impacts on life and property in the vicinity of the reservoir structure in case of a major spill or catastrophic failure.

4.8 Underground Chambers

Underground chambers may be required to accommodate valves, pumps or flow meters. These structures must meet all the requirements of the most current edition of the B.C. Building Code. Underground chambers should be located outside vehicular traffic areas and outside areas subject to flooding. They should be constructed of watertight reinforced concrete (pre-cast or cast-in-place). The chambers should be conveniently accessible through one of the following two options:

1. Low Hazard Confined Space

   Fully opening hinged roof hatch on top of shallow (minimum 1.5 m deep) chamber; step ladder access; roof hatch to be watertight and to be made of structural aluminum and with upper non-slip surface; roof hatch in appropriate sections that allow one person lifting/closing/arresting the hatch doors; roof hatch complete with safety chains and drainage system; hatch designed and rated for occasional/accidental vehicular traffic loads. Designs shall meet Workers Compensation Board (WCB) requirements for "Confined Space Entry".

2. No Confined Space

   Full height (minimum 2.0 m) buried concrete chamber with stairway and door access; steel security door (swings out) complete with deadbolt lock; stairway landing to allow door to open fully outwards; landing sloped 1% complete with floor drain and drainage discharge; stairs (complete with handrails) and landing must be lighted; inside chamber must be lighted and ventilated through positive forced ventilation.

Underground chambers that are only accessible through manhole openings should be avoided.

All exterior walls exposed to soil should be applied with minimum two layers of brush-on tar coating or one layer of a watertight torch-on membrane. In addition, a dimpled membrane should be installed between the sealed wall and the backfill material. The chamber foundation and floor slab should be protected by a perimeter drain system and a base material that is able to function as a capillary break. Joints of pre-cast concrete chamber sections should incorporate a factory provided seal. Floor slab – wall joints of cast-in-place concrete chambers should be sealed with waterstops. The interior floor of underground chambers should be sloped 1% minimum towards a grated sump. The sump should be drained by means of a sump pump or an automatic ejector if the chamber has no power supply. The interior walls of all chambers should be painted with a durable and white concrete sealer.

The piping (refer to Section 4.5.2) and equipment should form a rigid assembly resting on adequately spaced pipe supports. The centreline of the piping should be 500 mm minimum above the floor. With cast-in-place concrete chambers, sealing rings/plates welded to the main pipes at all wall penetrations should be cast into the walls. Weld-on sealing rings or plates should also be designed to function as a thrust anchor. Pre-cast concrete chambers should either provide sealing ring/plate slots at the horizontal chamber joint which can be injected with sealant/grout after pipe and chamber installation (this option requires an additional thrust blocking device to prevent pipe movement and damage to the injection/sealing area around the pipe penetration), or should be provided with a cast-in-place concrete thrust block accommodating the pipe sealing ring/plate just outside each major pipe wall penetration. Wall penetrations of smaller pipes such as drain pipes or conduits may be sealed with flexible or modular ring seals capable of forming a watertight wall penetration.

To prevent settling, underground chambers must be founded on suitable soils. In some cases, this may require over-excavating and replacing natural soils with proper compactable materials.

All underground chambers should have at least provisions for natural ventilation through a minimum of two vent stacks on opposite sides and opposite depths of the chamber. The vent stacks must extend to a height above grade to allow ventilation through a typical snow cover. Vent stacks should terminate above ground with a hood or gooseneck that is vermin proof. Vent stacks should be outside any traffic areas.

4.9 Water Treatment

In general, all B.C. community water systems must meet the requirements of the provincial Drinking Water Protection Act and the Drinking Water Protection Regulation. In addition, potable water quality should meet the Guidelines for Canadian Drinking Water Quality.

Design criteria for required water treatment facilities are stipulated by the local Health Authorities. Water systems are now typically required to meet the objectives of the 4-3-2-1-0 policy, initially introduced by the Interior Health Authority in January 2006. This policy is defined as follows:

- 4 log (99.99%) inactivation or removal of viruses
- 3 log (99.9%) inactivation or removal of Giardia and Cryptosporidium
- 2 treatment processes for all surface water sources for multi-barrier protection
- 1 nephelometric turbidity unit (NTU) or less of turbidity in water
- 0 E. Coli or fecal coliform bacteria

The design engineer should contact the local Health Authority for the project specific water treatment requirements. As a minimum and as part of the multi-barrier approach, all community water systems should provide chlorination for maintaining a minimum residual free chlorine concentration of 0.2 mg/L.

4.10 Electrical Design

4.10.1 General

Successful operation of a pumped water supply system depends on a secure supply of energy and proper control and protection of the equipment. Electrical equipment and supply and control systems should be properly designed, constructed and maintained in order to ensure satisfactory operation and safety to personnel.

The BC Safety Authority publishes and enforces regulations governing construction of electrical systems. The regulations are contained in the current edition of the Canadian Electrical Code Part I, as adopted and amended for use in British Columbia.

An electrical installation should be designed by a qualified professional engineer with expertise in power and control circuitry, electrical protection, safety requirements and the requirements of the water system, or by an electrical control company reviewed and approved by a qualified professional engineer. Design drawings featuring schematics, wiring diagrams and layouts must be signed and sealed by a professional engineer, and should be prepared prior to commencing the installation or purchasing equipment. The drawings must be submitted to the local electrical inspector, who can often make useful suggestions based on knowledge of local conditions. The electric supply utility should also be contacted for confirmation of electrical supply information. Other utilities such as telephone or cable companies etc. should be contacted if their services form part of the telemetric control or alarm functions.

All new electrical installations shall be inspected and approved by the local electrical inspector. Connection to the electric utility will be authorized only after the installation is inspected and accepted. The engineer should prepare record drawings and certify that the installation has been satisfactorily completed. If the record drawings are prepared by an electrical control company, they should be reviewed by an electrical engineer who should provide a signed and sealed letter stating that the installation was completed in accordance with the drawings and was tested and operates satisfactorily as designed.

The frequency and length of power outages and the storage capacity and drawdown rate of reservoirs are factors determining the need for standby electric generators (diesel or gas engine driven). A standby system shall meet both the Electrical Code and the electric utility's safety standards.

Single-phase services are generally adequate for small electrical systems. However, economics and electric utility regulations usually dictate the use of three-phase systems where motors larger than approximately 6 kW (8 hp) are required.

4.10.2 Power and Control System

Each electrical system requires:

- a kilowatt-hour meter owned by the electric utility;
- a service switch (circuit breaker type) that allows the whole of the electrical system to be disconnected from the supply;
- a surge protector on the main service;
- power distribution and control equipment for the pumps;
- adequate lighting for safe access and maintenance;
- adequate heat and ventilation;
- a supervisory control and data acquisition system (SCADA) for larger or more sophisticated water systems (multiple reservoirs and/or multiple pump stations)

Both manual and automatic control of the pumps is usually provided. Manual control is provided for testing purposes and also to permit pump operation upon failure of the automatic controls. The degree of automation required is a "value judgment" considering safety, economics, convenience and reliability.

Each pump should have the following controls:

- adjustable motor circuit interrupter for short circuit protection;
- magnetic contactor which incorporates an adjustable, manually re-settable, overload protection relay to monitor the motor current and shut down the pump if the current exceeds the motor manufacturer's recommended values;
- Hands-Off Automatic control selector switch;
- elapsed time meter to total the hours of operation of the pump;
- green indicator light which turns on when the pump is running;
- control Power-On light to allow the operator to determine if power is available to operate the controls;
- red alarm indicator light which turns on to indicate pump trouble;
- single phase protection for three phase systems;
- amp meter and phase switch (optional).

Single phasing, which can cause motor burnout, often results when one of the electric utility's distribution lines are broken and the other phases remain energized. A motor might continue to run when this occurs, although it cannot be started. Higher-than-normal current and overheating of the motor can result. Overload protectors are generally designed to provide single phase protection. The designer should confirm that the protector selected is adequate, or should provide a separate voltage-sensing type of relay to detect loss of one or more phases and shut down the motors.

A "lead-lag" pump-sequence manual selector switch or an automatic control alternator should be installed to even out the wear of pumps of similar size in a multiple-pump installation, instead of leaving a particular pump in the leading (first started) control position.

Multiple pump systems should have controls designed for time-delayed automatic restarting of the pumps which ensures staggered starting of the pumps after a power outage. This will avoid low voltage which could result in motor overheating, or magnetic controllers and relays dropping out (i.e., failing to maintain their contacts closed).

To reduce inrush currents during pump starts, pumps/motors of 7.5 kW or 10 HP or more should be controlled through a soft starter or a variable frequency drive (VFD). Soft starters should not be used to slowly ramp down pump motors during pump stops (soft stops). For waterhammer mitigation during pump stops, VFD's should be used.

A well pump should be provided with a protection device that will shut it off in the event that the well water level drops below a level that will adversely affect the pump operation. A number of methods are available to perform this protective function. A red alarm light requiring manual resetting should be provided to draw attention to the problem if it occurs. All other pumps should be provided with protective devices that will shut them off if there is a loss of water supply to the pump.

For booster pumping systems that do not include balancing storage, pumps should be controlled in a manner that does not adversely affect pump operation pump life and that does not consume excessive electrical energy.

Reservoir level control systems should use either loop-powered pressure transmitters or loop-powered ultrasonic transmitters. These devices can provide a remote level indication at the pump station and can provide operating levels for several pumps as well as high and low reservoir alarms. Any changes to operating levels can be made at the pump house. The high level alarm should override individual pump controls to shut off all pumps. Each level transmitter in any reservoir, holding tank or wet well that receives pumped flows should be backed up by a mechanical float switch set at a High High Level just before the overflow level. This float switch should override any pump controls, shut off all pumps and trigger an alarm.

4.10.3 Alarm Systems

An alarm system provides warnings of abnormal operations and functions and enables the system operator to quickly identify issues and respond to them in an expedient manner. In situations where part-time operators work in remote locations, it is very important to design alarm systems that provide the operators on call with sufficient warning and lead-time to enable them to travel to the sites and deal with the situations appropriately.

Alarm system signals can be transmitted by leased telephone lines, private lines or radio to an agency headquarters, a private home, portable communication equipment or any combination thereof. Alternatively or in addition, the alarm system can be designed to operate a light or audible device in a prominent location to attract attention. A separate electrical contact provided for each of the following alarm conditions can be used to initiate a general alarm signal. The following list is only a typical example of possible alarm signals in a simple water system and is by no means complete or suitable for every water system:

- motor overload
- power failure
- low pressure
- high pressure
- low reservoir level
- high reservoir level
- high high reservoir level (just before overflow)
- security (break-in)
- pump control failure
- standby generator trouble
- high chlorine
- low chlorine

The system design should make it possible to differentiate between the individual causes of alarms.

For larger and/or more sophisticated water systems, a SCADA system should be designed and installed in order to enable the operator to make a centralized assessment and review of the operations and to make necessary interventions. A SCADA system should be able to communicate with all controlled system components, Remote Terminal Units (RTUs) and Programmable Logic Controller (PLCs) and feature a user friendly Human-Machine Interface (HMI). Alarm functions should be incorporated into any SCADA system. The HMI system should preferably be designed and programmed in collaboration with the system operator(s).

4.10.4 Construction

Electrical equipment should be housed above ground with good ventilation. Floor drains should be provided with P-traps or screens to prevent entry of vermin.

Power, control and alarm wiring installed on poles is usually the least expensive form of construction but might be susceptible to damage from falling branches or trees, or vehicle accidents. Underground wiring is recommended as it can be directly buried or pulled through buried electrical ducts. Warning tape buried about 0.5 m above the underground wiring is required as it will caution anyone excavating in the area.

If installed outdoors, electrical equipment should be suitably enclosed and protected from moisture, extreme temperatures and vandalism. Outdoor enclosures should be esthetically pleasing, solidly founded or mounted, corrosion protected and situated in a location that provides vehicular access.

One meter minimum working space should be provided in front of the equipment for maintenance. Overhead wires should have proper clearance over vehicle access areas and should be located a safe distance from hatches.

5. DESIGN CONSIDERATIONS FOR OPERATION AND MAINTENANCE

In general, all system components should be designed for convenient operational and maintenance procedures. This includes, but is not limited to the following:

- a convenient layout of the system components with ample space to allow repair and replacement of equipment;
- placing equipment to facilitate visual inspections and routine maintenance;
- considering vehicular access to equipment locations to allow for tool and parts transport;
- considering potential future expansions and make provisions for such;
- design of an adequate control and alarm system to enable operators to react quickly and properly in emergencies;
- equipment sizing and selection that facilitates a long service life, low operational costs and low maintenance requirements;
- keeping the system as simple as possible but as sophisticated as necessary, considering the different implications due to a rural versus an urban setting;
- preparation of complete and useful record information in form of system and equipment drawings and specifications, system calculations, hydraulic models, user manuals and manufacturer/supplier contacts, flow charts, diagrams and Process and Instrumentation Diagrams (P&IDs), legal survey plans and address maps, etc. The essential information should be compiled in a proper O & M Manual for the water system.

The design engineer should attend start-up to check the operation and function of all system components, test the initial settings and explain the operation of the system to the owner(s) and operator(s).

Any well-designed and constructed system can fail because of inadequate maintenance. All equipment should be inspected and all functions checked regularly according to the O & M manual and the manufacturer's information.

Detailed records should be kept for the water system and include items such as equipment performance and maintenance work completed.

6. AS-BUILT DRAWINGS AND SYSTEM CERTIFICATION

Upon Deputy Comptroller's approval and issuance of a Certificate of Public Convenience and Necessity (CPCN), which authorizes the start of water system construction, and upon subsequent satisfactory construction completion, certified as-built drawings of the water system must be submitted to the Utility Regulation Section. These drawings should show the location of all the works, including buried works, by dimensions to legal survey lines and must be accurate to the nearest 0.3 m. Plan drawings should be on a legal composite base.

Key elevations should be shown, where appropriate, and distribution system drawings should show pressure zones.

All drawings should be signed and sealed by a professional engineer or limited licensee registered to practice in the Province of British Columbia. The same professional engineer should submit a letter certifying that the water system was constructed substantially in accordance with the as-built drawings and that the system was tested and disinfected in accordance with the B.C. Public Health Authority regulations and/or AWWA standards.

REFERENCES

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Well Protection Toolkit; B.C. Ministry of Environment, Water Protection and Sustainability Branch, 2000

Workers Compensation Act; WorkSafe BC, Workers Compensation Board, 2008

APPENDIX A: CLIMATE ZONE MAP