

Guidelines for Evaluating Applications for Recreational Use Permits at Domestic Water Supply Reservoirs

BACKGROUND INFORMATION

A. Legal Authority

The California Code of Regulations (CCR) prohibits recreational use of a domestic water supply reservoir unless it is specifically authorized in a water supply permit¹. The CCR also establishes minimum data requirements to accompany an application for recreational use².

The California Health and Safety Code (HSC) establishes as State policy that all public waters are to be used for multiple purposes, to the extent that the uses are consistent with public health and safety³. The HSC prohibits body contact recreation in a reservoir where water is stored for domestic use, but makes exceptions for all reservoirs in San Diego County, the Nacimiento Reservoir in San Luis Obispo County, and the Modesto Reservoir in Stanislaus County⁴. The California Water Code makes an additional exception for reservoirs constructed and operated as part of the State Water Project by providing that body contact recreation shall be permitted on all such reservoirs to the extent that it is compatible with public health and safety requirements⁵.

The above laws do not specifically address reservoirs that store water for multiple purposes, including domestic water supplies. In these cases, a domestic water supplier or group of suppliers generally does not control activities on the reservoir. They should, however, seek to establish an agreement with the entity that does control such activities to implement the guidelines outlined in this document.

B. Health Department Study and Previous Guidelines

In 1959 the California Legislature, which had been grappling with the issue of recreational use of reservoirs used as sources of domestic water, appropriated funds for the State Department of Public Health to study the impact of recreation on such reservoirs. The study, which was completed in 1961, drew the following general conclusions:

- Most of the reservoirs surveyed that were open for recreational use showed physical evidence of varying degrees of abuse and pollution (e.g., trash, human feces, etc.)
The study found a direct correlation between such abuse and poor, inattentive

¹ CCR, Title 17, §7626

² CCR, Title 17, §7627

³ HSC, §115825

⁴ *ibid.*

⁵ California Water Code, §12944(a)

management practices on the part of the entities responsible for the reservoir. Specifically, the report cited inadequate provision and maintenance of sanitation facilities, and insufficient personnel to supervise and control recreational activities, as being problems at most reservoirs that permitted recreation.

- Notwithstanding the physical evidence, the study found that concentrations of indicator organisms (i.e., total coliform, fecal coliform, and fecal streptococci bacteria) were not significantly greater at the heavily used reservoirs than at those that were closed to recreation. Also, there were not significant differences between the heavily used parts of an open reservoir and the parts of the same reservoir that were less heavily used.
- The report concluded that non-body contact recreation would not adversely impact the quality of water in domestic water supply reservoir provided that adequate sanitation facilities and control of recreation activities were provided.

Based in part upon the concerns identified in the 1961 report, in 1974 the Water Sanitation Section of the California Department of Health developed a set of guidelines for controlling recreational and other development at reservoirs used for domestic water supply. The guidelines covered both reservoirs primarily used for domestic supply and reservoirs providing water storage for a variety of purposes, including domestic supply. The guidelines address water intake protection, sewage collection and disposal facilities, toilets, refuse disposal, water-oriented recreation, equestrian activities, and other aspects of recreation management.

C. Recent Developments

In the 1980s and 1990s two pathogenic organisms were identified as important causative agents in waterborne disease - *Giardia* and *Cryptosporidium*. These pathogens are very difficult to detect using standard analytical techniques (e.g., recovery rates from spiked samples collected pursuant to California's implementation of the federal Information Collection Rule ranged from less than 1% to 4%), and show poor correlation with commonly used indicator organisms. As a result, recognition has grown among water suppliers and regulatory agencies that indicator organisms are of limited usefulness in predicting the safety of water sources.

In 1995 the Metropolitan Water District of Southern California (MWD) took a new approach for determining the appropriate level of recreational activity for its new Eastside Reservoir in Riverside County. Using published data and a flow model for the new reservoir, MWD hired a group of experts to perform microbiological risk assessments of various recreation use proposals. The assessment was made as follows:

- Using published data, rates of pathogen release were estimated for recreators in various age groups.
- These rates were applied to the projected numbers of recreators for each age group for the various use proposals to determine the range of pathogen loads that could be anticipated.

- These loads were used as part of model calculations to estimate the range of pathogen concentrations in the reservoir outflow, taking into account die-off in the reservoir.
- These concentrations were used to estimate the additional risk of infection posed by the various recreation use proposals for those using the treated water for drinking, taking into account the reduction of pathogens by the treatment process.

The assessment was evaluated by an independent scientific peer review panel, which agreed with the methodology employed and recommended some refinements. MWD used the assessment as a basis for its decision to restrict body contact recreation on the Eastside Reservoir. A paper on the study has been published in the scientific literature⁶.

Contra Costa Water District (CCWD) used MWD's methodology and some of the results of the Eastside Reservoir assessment to perform a similar assessment of recreational use of Contra Loma Reservoir, which it uses intermittently as a source of supply. This reservoir is much smaller than the Eastside Reservoir (2,457 acre-foot capacity vs. 800,000 acre-feet) and is very intensively used for swimming (approximately 80,000 visitors in 1997). CCWD's assessment indicated that the incremental risk posed by the recreational use is 4 to 67 times higher than U.S. EPA's target of 1/10,000 annual risk of infection for treated surface water⁷.

D. Purpose, Scope and Organization of Current Guidelines

The purpose of these guidelines is to help ensure the safety of California's potable water supply by controlling sources of contamination on reservoirs used by public water systems. The guidelines incorporate the criteria from the 1974 version, expanding on or modifying them where applicable. In particular, the guidelines provide for the incorporation of a microbiological risk assessment in a recreational use permit application when body contact recreation is allowed. This is necessary because many reservoirs are excluded from the statutory prohibition of body contact recreation, and are subject to contamination by *Giardia*, *Cryptosporidium*, and enteric viruses from such activities.

The guidelines provided below generally follow the outline set forth in the CCR for data that must be submitted with an application for a recreational use permit.

⁶ Anderson, *et al.* 1998. "Modeling the Impact of Body-Contact Recreation on Pathogen Concentrations in a Source Drinking Water Reservoir"

⁷ U.S. EPA, 1989, Final Surface Water Treatment Rule; *Federal Register* 54, 124, 27486

PROPOSED GUIDELINES

A. Reservoir and Watershed Information

The permit application must include maps showing the reservoir and its surroundings. The information provided should include the following:

- the location of water works facilities (i.e., reservoir inlets or tributaries, reservoir outlets, controls, any treatment works, etc.),
- the topography of the reservoir (including subsurface) and its immediate watershed (i.e., within approximately 1 mile of the shoreline),
- the location of the shoreline at anticipated high and low water levels,
- prevailing currents in the lake,
- the areas to be open for different types of recreational use,
- locations of any intakes used to supply water for recreational use areas,
- locations of activities and/or facilities that have the potential to contaminate the water supply (e.g., horse stables),
- the location of wastewater collection, treatment, or disposal facilities in the proximity of the reservoir, including information on the degree of treatment provided and any reliability features,
- locations of toilets to be provided for the public, and
- information on the quality of the water in the reservoir (i.e., results of any microbiological, chemical, turbidity, and radiological monitoring).

The application must also include data on the reservoir. The information provided should include the following:

- the physical dimensions of the reservoir,
- the range of water level fluctuations,
- its storage capacity and shoreline length at anticipated high and low water levels,
- the residence time for water stored in the reservoir at anticipated high and low water levels,
- the topography of the reservoir site, and
- the occurrence of wind-induced currents, natural or man-induced turbulence, thermal gradients, a thermocline, or other factors that may affect the quality of the stored water and movement of possible contaminants to the water intake from various points in the reservoir.

B. Protection of the Reservoir Outlet

The application must include data on the protective zone (i.e., the area in which recreational activities are prohibited) to be provided around the reservoir outlet. Information provided should include the following:

- the extent of the protective zone, and the basis for determining the extent (i.e., conformance with standard guidance or a site-specific study of flow dynamics)

- the distance from the protective zone to various areas of recreational use (e.g., swimming areas, boat docks, etc.), and
- a description of the program to prevent encroachment into the protective zone (i.e., physical barriers, postings, informational brochures, and patrolling).

The protective measures for the outlet must, as a minimum, meet the following criteria:

- Provide a closed zone around the outlet within which all recreational use is prohibited. Mark the zone with buoys and a cable line to prevent boats from entering. Provide posting and patrol to prevent public access. Prohibit anchoring of boats on the buoy line.
- The closed zone should extend for a minimum distance of 500 feet from the reservoir outlet works.
- Close the shoreline area extending 500 feet on either side of the outlet by fencing. The area should be posted, both in the water and along the shoreline. The area should be patrolled at least daily and more often during peak use periods.
- Streams or drainage ways flowing into the reservoir within the closed zone should be protected by closing their tributary watersheds to recreational development or cattle grazing within 500 feet of the reservoir shoreline.

A site-specific study of flow dynamics may be undertaken to determine whether the standard 500-foot setbacks provided above are either adequate or necessary.

C. Recreational Activities

The application will provide information on the recreational activities that will be allowed on or around the reservoir. Information provided should include the following:

- a description of the various types of recreational use that will be allowed (e.g., camping, hiking, boating, fishing, skiing, personal water craft, swimming, horseback riding), and
- the maximum daily number of persons, cars, vehicles or boats that will be allowed in the area during peak periods, and
- the average, minimum, and maximum total number of persons, cars, vehicles or boats that use the area on an annual basis.

D. Control Program

The application will include a description of the program to control recreation activities on the reservoir. Information provided should include the following:

- the control policies and objectives that the program will implement,
- the entity responsible for carrying out the program,
- the governmental agency responsible for regulatory oversight of the program,
- the numbers and qualifications of personnel who will control recreation activities,

- the times when such personnel will be present,
- a description of the activities and duties of control personnel including a tabulation of how much time will be spent performing these and other tasks (if any),
- how the control program will be financed,
- a description of the types of sanitation facilities provided and their placement with respect to use areas, the waterline of the reservoir, etc.
- a description of how sanitary and recreational facilities will be maintained in a sanitary and aesthetically acceptable condition, including a maintenance schedule for these facilities.

Program Policies

The program should implement the following restraints on recreational activities and the facilities that support them:

1) Boating Activities

If boating in other than agency-owned and operated boats is allowed, the agency responsible for the operation of the recreation area should adhere to the following requirements:

- a) Vessels with any form of portable toilet capable of being emptied into the reservoir must be prohibited. In some cases, the Department of Health Services (DHS) may request that all boats with any form of toilet or sink be excluded from the reservoir.
- b) The reservoir must be open to boating only when the operating agency can maintain an adequate patrol.
- c) Boat-washing facilities should be provided for rental and private boats. All waste from such facilities must be removed to an on-shore disposal system.
- d) A responsible person must be on duty at all times at the launching ramps when the ramps are in operation to inspect all boats being launched to ensure compliance with applicable regulations.
- e) Containment features must be provided at all fuel-loading facilities to prevent fuel spillage into the reservoir. Storing fuel in containers over the water must be prohibited.
- f) Floating restaurants, snack bars, or other similar types of facilities that require disposal of sewage or other waste should be prohibited.
- g) Patrol personnel must enforce the provisions of the California Harbor and Navigation Code and all applicable local regulations.
- h) A safety inspection program must be implemented to ensure that boats are equipped with a life preserver for each passenger and to regulate the number of persons that can be carried by each boat.
- i) Fish cleaning facilities with adequate water supply and waste disposal systems must be provided. These facilities should be set back from the high water line by at least 100 feet. Prevent the overflow of waste from this facility into the reservoir.

2) Swimming

At reservoirs where swimming is allowed, the following precautions must be observed:

- a) In order to maximize pathogen attrition in the reservoir, swimming areas should be located as far from the reservoir outlet as possible, and situated where prevailing currents will not allow rapid transport of water from the swimming area to the outlet. A site-specific analysis of flow dynamics is strongly encouraged.
- b) In order to reduce the introduction of fecal matter into the reservoir, diaper-wearing infants should be prohibited from water contact.
- c) Dogs and other domestic animals should be prohibited from swimming areas.

3) Toilets

Toilets must be sufficient in number, conveniently located, readily accessible to the public, and maintained in a clean, sanitary fashion at all times.

- a) Toilets must be provided for each sex in proportion to the number of visitors expected. The recreational facility manager may either perform a study to determine the appropriate number of toilets, or may use the following criteria:
 - Picnic areas, playgrounds, beaches, and other general use areas: 50 persons per toilet. The facilities must be centrally located and easily accessible.
 - Camping areas: 20 persons per toilet. Each campsite must be no more than 400 feet from a toilet.
 - Designated shore-fishing areas: 70 persons per toilet. The toilets must be located no more than 500 feet apart at regular intervals along the shoreline.
- b) Toilet facilities must be convenient and available to the boating public in all areas of the reservoir that are open to recreation. Only parts of the shoreline where toilet facilities are available within a 5-minute walk (or, alternatively, within 500 feet) should be open for recreation.
- c) Toilet facilities must be available within two miles of any point of the reservoir, and provided with a dock for easy access.
- d) Toilets must be emptied and cleaned daily in developed areas during the recreation season. At other times, and in remote areas, toilets must be emptied and cleaned at least once a week.
- e) The following types toilets are permitted for use at reservoir areas, subject to the indicated constraints:
 - **Water flush toilets** are preferred by the public, and should be provided wherever possible. Such toilets must be set back least 200 feet from the high water line of reservoirs and lakes, unless otherwise approved by the health officer. A dike should be placed around the facility to prevent overflow to the reservoir. An alarm system to alert maintenance personnel of an overflow condition is strongly recommended.
 - **Chemical toilets** are recommended to supplement water flush facilities during peak-use periods. They should also be provided in limited and seasonal use areas, and in gently sloping areas where the fluctuating water levels can cause wide variations in the shoreline. The toilets should be located at least 50 feet (horizontal distance) from the existing water line of lakes and reservoirs and anchored to prevent overturning. The tank must be

emptied before filled within 12 inches of the seat, using procedures designed to prevent spillage. The toilets must be moved to higher ground when the water level begins to rise in the reservoir.

- **Vault and pit privies** may be used in remote areas where recreational use is limited. The toilets should be set back at least 100 feet from the high water level of the reservoir. When the pit is filled within 18 inches of the floor slab, empty or move the privy and adequately cover the pit.
- **Floating restrooms** should be prohibited unless special approval is obtained from DHS.

4) Trailer Sanitation Stations

Camping areas that allow van conversions, trailers, or recreational vehicles must provide sanitation stations to receive the discharge of sewage holding tanks. At least one such facility must be provided for every 100 vehicles. Sanitation stations must be set back at least 200 feet from the reservoir high water line, and must be approved by the local health department. In all areas open for recreation vehicles with sewage drains must be prohibited within 50 feet of the reservoir shore.

5) Individual, Onsite Sewage Disposal Systems

Where residential or commercial sewage disposal is by means of individual septic tanks and leaching systems, the following is required:

- a) Onsite sewage disposal systems must be designed by a registered Civil Engineer on the basis of percolation tests conducted at the site.
- b) An alternative disposal system must be available if the regular system fails to function.
- c) An overflow tank at the terminus of the leaching system must be provided and inspected at least weekly to warn if the system is failing.
- d) Onsite sewage disposal systems must be set back from the reservoir high water line at least 200 feet, and must be at least 10 feet above the high water line. Such systems must be prohibited from the shoreline portion of the closed zone at the reservoir outlet.
- e) Plans for onsite sewage disposal systems must be submitted to the local health department for review and approval by prior to construction.

6) Sewerage Systems

Where sewage is handled by an integrated collection and disposal system, the following is required:

- a) Sewers and appurtenances must be at least 10 feet above and over 200 feet away from the high water line of the reservoir or lake.
- b) Sewerage facilities must be designed and built to prevent overflow or leakage. Sewer lines and manholes must be durable and watertight. Manhole structures must have watertight covers.
- c) Sewage pumping stations and force mains must be designed on a fail-safe basis. Pump stations must be provided with at least two pumps, failure alarms, emergency storage, and standby power or portable, independently powered pumps.

- d) All failure alarms on the various portions of the sewerage system must have an independent power source (e.g., a battery). The alarms must be connected to a station that is manned 24 hours a day.
 - e) A public agency must operate and maintain the sewerage system.
 - f) A Grade IV California Wastewater Treatment Plant Operator must be designated to operate the sewerage system.
 - g) All portions of the sewerage system must be outside the closed zone at the reservoir outlet.
 - h) New sewage treatment plants and effluent disposal areas must be located at least 1 mile away from the shoreline the reservoir, and if possible, off the watershed.
 - i) If an existing sewage treatment plant is located on the watershed, the following restrictions apply:
 - The treatment plant must be set back at least 500 feet from the reservoir high water line.
 - The plant site must be enclosed by a dike, or another means must be provided to contain any overflow.
 - The treatment plant must be designed on a fail-safe basis with dual facilities, failure alarms, a minimum of 24 hours emergency storage, and standby power.
 - j) If an existing effluent disposal area is located on the watershed, the following restrictions apply:
 - Effluent disposal to the reservoir must be prohibited.
 - The effluent disposal area must be set back at least 1,000 feet from the reservoir high water line.
 - Surface drainage from adjacent areas must be diverted around the disposal area. Adequate facilities must be provided to prevent any runoff or overflow from the disposal area. Effluent storage requirements are ten days for spray disposal, and three days for subsurface percolation.
- 7) Refuse Disposal
Dumping of refuse into the water or along the shoreline of the reservoir and tributary streams must be prohibited. Conveniently located, covered, and anchored refuse containers must be provided in all areas open for recreation. A sufficient number of such containers must be provided to accommodate refuse generated during peak use periods. An approved waste collection and disposal entity must transport refuse off the watershed for disposal.
- 8) Equestrian Activities
Equestrian activities must be subject to the following controls:
- a) Prior to construction the local health department must approve the location and operating plans for all corrals, stables, staging areas, and trails.
 - b) Before an area is open to equestrian use a suitable ordinance or regulation acceptable to the local health department must be established to control the equestrian activities.

- c) Horses must be prohibited from entering the reservoir or any tributary stream within 200 feet of the reservoir shoreline. The operator of the equestrian recreation facility must implement a program of fencing, posting, and patrol to accomplish this objective.
- d) All trails must be set back at least 100 feet from the reservoir high water level.
- e) The operator of the equestrian facilities must provide the public with copies of all applicable ordinances in a brochure that prominently states that the reservoir is a source of domestic water supply and must be protected.
- f) Stables or corrals should not be located on the reservoir watershed. If this is not possible, the following restrictions apply:
 - These facilities must be set back at least 1,000 feet from the high water level of the reservoir.
 - The maintenance program for stables and corrals must provide daily collection of manure at all corrals and stable areas, and transportation to a storage or disposal area off the watershed.
 - Storm water drainage from stables and corrals must be prevented entering the reservoir insofar as feasible. Storm water from adjacent areas should be diverted away from stables and corrals.

9) Visitor Limitation

In order to prevent overuse of the area and creation of health or safety hazards, the number of persons, boats and trailers, that are allowed to use a recreation area must be limited to avoid exceeding the capacity of sanitation and other support facilities. These limits must, at a minimum, conform to the criteria provided above for refuse containers, toilets, and trailer sanitation stations.

As noted on page 1, some domestic supply reservoirs are exempted from the statutory prohibition of body contact recreation. If such recreation is allowed on a domestic supply reservoir, the number of visitors must be further limited in order to prevent the contamination of the raw water supply with excessive numbers of pathogenic organisms. The following table⁸ provides some guidelines for determining the appropriate limits. Reservoirs that allow numbers of visitors exceeding these guidelines should be evaluated using a biological risk assessment, as described in section E. below.

Type of body contact recreation allowed on reservoir	Annual number of visitors per acre-foot in storage capacity ⁹
water skiing/personal watercraft; no swimming	3.2
swimming	2.1

It should be noted that the values given in the above table assume there is no thermocline effect. If such a condition is known to exist during the period when body-

⁸ Adapted from method used by Anderson, 1999. "Estimated Pathogen Concentrations in the Contra Loma Reservoir and Associated Risks to Consumers and Recreators"

⁹ Average volume above thermocline during peak visitation period

contact recreation takes place, only the volume of water above the thermocline should be used in calculating the visitor capacity.

10) Water Quality Monitoring

If body-contact recreation is allowed, the reservoir must be monitored for microbial quality. This monitoring should consist of the following elements:

- *Parameters:* At a minimum, samples should be collected for total and fecal coliform bacteria. Samples for *E. coli* and enterococcus bacteria are also recommended. In addition, samples should be collected for protozoa (i.e., *Giardia* and *Cryptosporidium*).
- *Frequency:* Bacteriological samples should be collected at least weekly, and during a peak use period (usually a weekend afternoon.) Protozoa samples should be collected at least monthly.
- *Locations:* At least one sample should be collected for bacteriological analysis from each swimming or dock area, and from the reservoir inlet(s) and outlet(s). Protozoa samples should be collected from the reservoir outlet.

11) Reservoir Area Closure

The recreation administrator or manager must be authorized to close a reservoir to recreation under conditions such as the following:

- a) When the safety of the stored domestic water supply may be jeopardized.
- b) When the number of visitors is too small to justify providing the necessary supervision.

In addition, the Department’s draft “Guidance for Freshwater Recreational Areas” provides criteria for posting and closing a recreational area due to excessive microbiological hazard to bathers. While not directly related to protection of the water quality for domestic purposes, these criteria are provided below for the reader’s convenience.

A recreation area should be posted (or closed, at the discretion of the local health officer) when water quality monitoring indicates that levels of indicator organisms exceed any of the following values:

Parameter	Single Sample	30-day Average
Total coliform	10,000/100 ml	1,000/100 ml
Fecal coliform	400/100 ml	200/100 ml
<i>E. coli</i>	235/100 ml	126/100 ml
Enterococcus	61/100 ml	33/100 ml

12) Reservoir Patrol

Full-time patrol personnel must be provided to supervise and control visitors, and prevent nuisance conditions and unsafe activities. The number of personnel provided should depend upon the number of visitors according to the following criteria:

Body Contact Recreation Prohibited	Body Contact Recreation Allowed
1 per 500 persons or less	1 per 200 persons or less
2 per 1,500	2 per 1,000
3 per 2,500	3 per 1,500
4 per 4,000	4 per 2,000
5 per 5,000	5 per 2,500
	6 per 3,000

Additional personnel should be provided for larger crowds or large recreation developments, especially during peak use periods, to assure proper supervision and control of the visitors in all areas open to recreational use.

Boat patrols must be provided at reservoirs where boating is permitted. The number of boat patrols should be sufficient to police the entire reservoir at least twice daily. Boat patrols should be provided with radio communication equipment or cell phones. If high-speed boats are permitted to use the reservoir, the patrol boat should be capable of pursuit.

13) Emergency Plan

The agency responsible for the operation of the reservoir should develop an emergency plan to be implemented if there is an actual or threatened water contamination incident. The emergency plan must include notification of the State and local health departments as well as the water purveyor(s) taking water from the reservoir.

14) Public Health Surveillance

The local health agency of jurisdiction should provide public health surveillance of recreation activities at a reservoir. The reservoir operator should negotiate a contract with the local health department to provide this service. This contract should provide for at least one inspection per month of the recreation area by a registered Environmental Health Specialist. A detailed inspection form should be completed during the inspection, with copies furnished to the operator and DHS.

15) Public Notification

Visitors must be effectively informed that the reservoir is used for drinking water purposes and must be protected. The information program should have the following elements:

- Indicate on all informational bulletins that the reservoir is a source of domestic water supply and shall not be polluted.
- Provide all persons entering the recreation area with copies of ordinances or similar informational material relating to the protection of the water supply.
- Locate large permanent signs throughout the recreation area indicating that the reservoir is a source of domestic water supply. Signs in swimming areas should also indicate that domestic animals are not allowed, and that diaper-wearing infants must be kept out of the water.

- Provide decals for posting inside all rental and all private boats indicating the need for protection of the stored water supply.

E. Biological Risk Assessment

In cases where the annual number of visitors exceeds the guidelines provided in Section D.9 above, the application should include a numerical analysis and estimate of the anticipated densities of critical pathogenic organisms (i.e., *giardia* cysts, *Cryptosporidium* oocysts, and enteric viruses) at the reservoir outlet, and how these concentrations vary with recreational use patterns, reservoir levels, and flow conditions. This is especially appropriate when body-contact recreation is allowed in a reservoir. The analysis should take into account the information provided pursuant to items A through D above. The analysis must be carried out by persons with expertise in microbiological risk assessment and reservoir flow modeling, and should use the following general format:

- Estimate the average number of infected recreators (pathogen carriage).
- Estimate the amount of fecal material and the concentration of the critical pathogens in the feces that will be introduced by an infected recreator in contact with the water. The latter should take into account both the shedding of residual fecal material and the occasional accidental fecal release (AFR).
- Estimate the numbers of pathogens entering the water at various locations based on the number of recreators, their age distribution, the percent infected, and the number of pathogens that would be introduced through shedding and AFRs.
- Develop a hydraulic model of the reservoir that will predict the transport of pathogens from their point of entry to the outlet, taking into account pathogen attrition in the reservoir.
- Estimate the range of densities of pathogens in the reservoir outlet, taking into account daily, weekly, and seasonal variations in recreational use, water level, flow patterns, and water temperature.
- Determine the pathogen reduction efficiency for the water treatment plant(s) drawing water from the reservoir.
- Estimate the infective pathogen concentration in the potable water supplies based upon the raw water pathogen densities and the treatment plant efficiencies.
- Estimate the risk of infection based on the concentration of infective pathogens in the potable water supply, infective dose, and quantity of water consumed.

Evaluating the Risk Assessment

1) Assumptions

The risk assessment outcome is highly dependent upon the initial assumptions made regarding infected populations, pathogen concentrations in fecal material, the rate at which fecal material/pathogens are released during body-contact recreation, and the survival rates for the various pathogens. The following table lists some of the rates

assumed in the MWD Eastside Reservoir study, which reflect comments received from a scientific peer review panel.

Parameter	Values used in MWD Study
<i>Giardia</i> Infection Rate	0 – 10%
<i>Cryptosporidium</i> Infection Rate	0 – 5%
Rotavirus Infection Rate	5 – 20%
Poliovirus Infection Rate	5 – 20%
Feces shed per person	10^{-3} – 10^1 g
Accidental fecal release (AFR)	1 AFR per 1,000 recreators 50 – 200 g/AFR
<i>Giardia</i> per gram of feces	10^5 – 10^7
<i>Cryptosporidium</i> per gram of feces	10^5 – 10^7
Rotavirus per gram of feces	10^7 – 10^9
Poliovirus per gram of feces	10^6 – 10^8

The MWD assessment used the following rates for pathogen attrition in the Eastside Reservoir:

Zone	Crypto.	Giardia	Rotavirus	Poliovirus
Epilimnion	0.016 – 0.15 day ⁻¹	1.1 – 1.65 day ⁻¹	0.1 – 0.5 day ⁻¹	0.28 – 0.88 day ⁻¹
Hypolimnion	0.008 – 0.020 day ⁻¹	0.04 – 0.13 day ⁻¹	0.05 – 0.25 day ⁻¹	0.14 – 0.44 day ⁻¹

The above rates reflect the current state of the science and will probably be used in other risk assessments. Assessments using rates that differ greatly from the ranges listed above should be questioned.

Finally, the USEPA has recently determined that a water system that meets the requirements of the Long-Term Surface Water Treatment Rule can reliably provide the following pathogen reduction rates:

Pathogen	Reduction Rate
<i>Giardia</i>	99.67% (2.5 logs)
<i>Cryptosporidium</i>	99.9% (3 logs)
viruses	99.99% (4 logs)

2) Interpreting the Results

The range for a given parameter can cover several orders of magnitude, making a deterministic evaluation of risk very difficult. One way to overcome this difficulty is to run a number of statistical simulations in which one or more parameters are varied to develop a range of possible risks. A typical way to interpret these results is to determine an upper confidence level (usually 90th-99th percentile) within which most of the results fall.

In promulgating the Surface Water Treatment Rule, the USEPA established a risk goal of one infection per 10,000 people per year (i.e., 10^{-4} annual risk of infection). The risk assessment should produce a result comparable to this number at the 90%+ confidence level. If it does not, some adjustments to the restrictions on body-contact recreation should be considered (e.g., providing a separate impoundment for swimming). Alternatively, some modification of reservoir operation (e.g., drawing from below the thermocline during summer months) or upgrading the treatment process to increase pathogen reduction could achieve the same effect in certain situations.

Infrequent events that result in a high concentration of pathogens reaching the reservoir outlet (e.g., an AFR near the outlet) challenge the treatment system, and pose an acute significant risk of infection that will not necessarily be reflected in the annual risk analysis. The risk analysis should assess the possible risk of infection from such events on a daily, rather than an annual basis. If the assessment indicates an unacceptably high degree of risk, steps should be taken to abate it (e.g., providing a larger closed zone around the reservoir outlet).