Hopi Tribe

Wellhead Protection Manual

September 30, 1996

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1. INTRODUCTION

Daniel B. Stephens & Associates, Inc. (DBS&A) was retained by the Hopi Tribe to prepare a Wellhead Protection Manual that provides general guidelines on wellhead protection. These guidelines are intended to outline the steps toward developing a comprehensive wellhead protection program.

The purpose of a wellhead protection program is to protect the water supply for the residents of the Hopi Reservation and to safeguard health, resources, and property in the vicinity of existing and potential water supply wells and springs. This manual is also intended to provide general guidance on defining areas to be protected and the sources of contamination to avoid in these areas. Specific components of the wellhead protection program, such as defining and regulating exclusion zones, are beyond the scope of this guidance manual. These more complex issues will be addressed as a comprehensive wellhead protection program is implemented.

2. DEVELOPMENT OF A WELLHEAD PROTECTION PROGRAM

U.S. Environmental Protection Agency (EPA) Guidance (EPA, 1991b) outlines the following five steps that are necessary to develop a wellhead protection program:

1. Form a community planning team
2. Define the land area to be protected
3. Identify and locate potential contaminants
4. Manage the protection area
5. Plan for the future

A general description of the major elements of the five steps are provided below.

2.1 Form a Community Planning Team

The community planning team should represent all interests within the Hopi community. These may include Hopi villages, water suppliers, elected officials, government agencies (health, planning, and natural resources), businesses, land developers, community service organizations, environmental groups, farmers, and interested citizens. Technical input from a hydrologist, engineer and/or land planner will enhance the effectiveness of the team.

The purpose of the community planning team is to develop a wellhead protection program that incorporates the interests and concerns of the community. Community involvement is essential to ensure widespread support for the wellhead protection program. Thus, compliance with the protection guidelines will be easier to achieve.

Once a community planning team has been established, it should define clear goals and objectives for developing wellhead protection measures. The community planning team will then identify the land area to be protected, potential threats to water quality, regulatory controls, and future water supply needs to incorporate into the wellhead protection program.

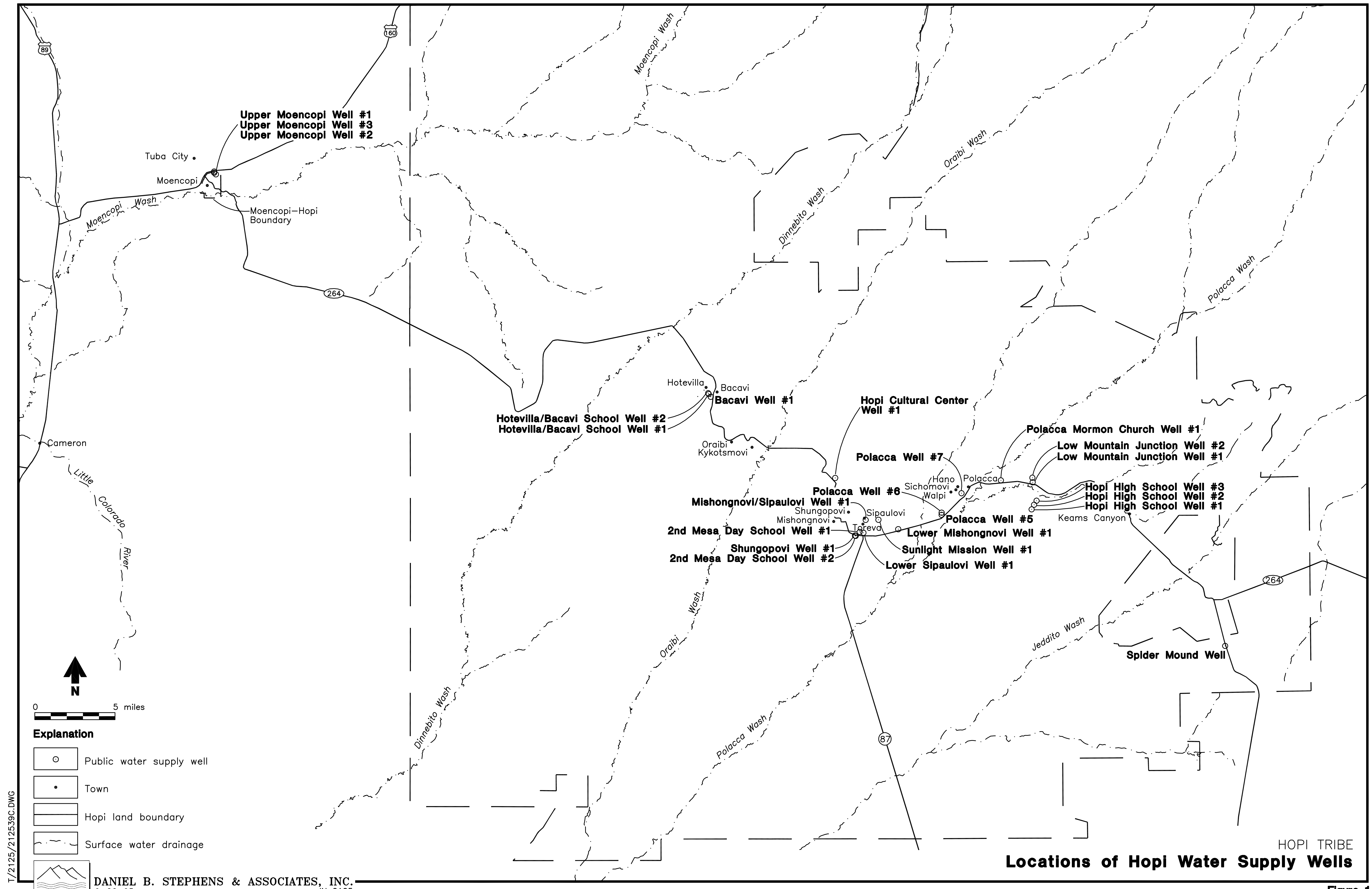
2.2 Define the Land Area to Be Protected

The community planning team will need to identify the land area that will be managed to protect Hopi ground-water supplies. The ground-water protection areas will be defined by determining the land area where, if contaminants were discharged at the surface they could potentially migrate to the well within a specified time. Each area that needs to be protected is called the "wellhead protection area" (WHPA). The first step in delineating WHPAs is to identify all wells that will require protection under the wellhead protection program.

Hopi community water supply wells that are currently providing water supplies for Hopi residents are shown on Figure 1. Although community wells are usually addressed through a wellhead protection program, the community planning team should discuss this issue and decide whether or not to also include individual domestic, livestock, or irrigation wells. Technical procedures for defining the WHPAs can vary from using a default radius, such as 3,000 feet around each well, to complex numerical modeling that simulates the cone of depression and capture zone around each well. More detail regarding the delineation of WHPAs is provided in Section 3.

The Hopi community water supply wells shown on Figure 1 are completed in the N-aquifer and, in some cases, possibly the D-aquifer. With the exception of the Moencopi area (Figure 1), all of the supply wells are completed in a confined aquifer. These wells and their zones of production are typically over 1,500 feet deep, and the extraction zones are separated from the surface by one or two confining layers of substantial thickness (the Mancos Shale and/or the Carmel Formation). Consequently, migration of contaminants from the surface to the zone of well completion through the natural formation is not the greatest issue of concern near most of the Hopi villages.

One potential pathway for surface contamination is through the annular space outside the well casing if the well boreholes are not sealed properly. The interim policy for wells and well drilling adopted by the Hopi Tribe addresses this issue for all water supply wells constructed in the future. Additionally, the Hopi Tribe Water Resources Program is currently developing standard well construction specifications and guidance for well pad construction. However, existing water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T/2125/212539C.DWG
DANIEL B. STEPHENS & ASSOCIATES, INC.
9-26-95
JN 2125
Figure 1

supply wells are potential pathways for surface contaminants to travel to the aquifer, and delineation of wellhead protection zones in these areas is therefore a priority.

In addition to the water supply wells, many of the Hopi villages use springs for drinking water and ceremonial purposes. Since many of the springs emanate from the near surface Toreva or Wepo Formation, protection of these areas from potential surface contamination is also a priority. Consequently, it is recommended that the wellhead protection program also be applied to springs. In this document, the terms well or wellhead also include springs.

2.3 Identify and Locate Potential Contaminants

When the WHPAs have been defined, the community planning team will need to identify and locate the potential threats to the quality of the ground-water supplies within these areas. In theory, any pollutants released within the WHPA will have the potential to contaminate the ground-water supply, and therefore, such contaminants should be eliminated or managed very carefully in these areas.

The Hopi Tribe Water Quality Assessment Report (DBS&A, 1993) discusses some of the major sources of pollutants on the reservation and includes maps of mining sites, dumping sites, underground storage tank sites, and sewage lagoons. Other information on sources of contamination on the Hopi Reservation may be obtained from the following:

- Phone book for businesses that may use potential contaminants
- Police and fire department records
- Tribal government records
- State of Arizona Department of Environmental Quality records
- EPA records regarding underground storage tank (UST) sites and other environmental concerns
- Bureau of Indian Affairs records
- Indian Health Service records

Table 1 is a comprehensive list of sources of contamination that may be of concern; Table 2 lists principal sources of contamination that have been identified on the Hopi Reservation. Based on a review of existing data, the following are highest priority sources of pollution on the Hopi Reservation:

- Septic tanks
- Sewage lagoons
- Active and/or abandoned mines
- Abandoned or unauthorized dumping areas (includes dumping of household and small business hazardous waste)
- Underground storage tanks

These contaminant sources have been addressed to some extent in existing Hopi programs. For example, the Solid Waste Program has already conducted education to curtail open dumping, and some of the sewage lagoons have been addressed by the Water Resources Program. However, continuing efforts to eliminate these sources of contamination should be included in the wellhead protection program.

One of the key issues to be addressed in terms of regulating contaminant sources is how to deal with existing sources (such as USTs) that are near wells or springs. While the wellhead protection program will likely define an exclusion zone for the installation of new USTs, existing USTs or other sources will have to be addressed separately. The community planning team should consider funding and economic constraints when determining how to regulate existing potential sources.

2.4 Manage the Protection Area

Once the WHPAs have been defined and the existing sources of contamination identified, the management of these areas can be controlled by the Hopi Tribe and/or appropriate village governments. Management of activities within the WHPA (subdividing land, building roads, constructing and using buildings) can be obtained through both regulatory and nonregulatory controls.

Table 1. Potential Sources of Ground-Water Contamination

Source	Health, Environmental, or Aesthetic Contaminant [a, b, c]
Naturally occurring sources	
Rocks and soils	*Aesthetic contaminants:* Iron and iron bacteria; manganese; calcium and magnesium (hardness)
	Health and environmental contaminants: Arsenic, asbestos, metals, chlorides, fluorides, sulfates, sulfate-reducing bacteria, and other microorganisms
Decaying organic matter	Bacteria
Geological radioactive gas	Radionuclides (radon, etc.)
Natural hydrogeological events and formations	Intrusion of poor quality (i.e., brackish) water; contamination by a variety of substances through sink-hole infiltration in limestone terrains
Agricultural Sources	
Animal feedlots and burial areas	Livestock sewage wastes; nitrate; phosphate; chloride; chemical sprays and dips for controlling insect, bacterial, viral, and fungal pests on livestock; coliform [d] and noncoliform bacteria; viruses
Manure spreading areas and storage pits	Livestock sewage wastes; nitrate
Livestock waste disposal areas	Livestock sewage wastes; nitrate
Crop areas and irrigation sites	Pesticides [e]; fertilizers [f]; gasoline and lubrication oils from chemical applicators
Chemical storage areas and containers	Pesticide [e] and fertilizer [f] residues
Farm machinery areas	Automotive wastes [g]; welding wastes
Agricultural drainage wells and canals	Pesticides [e]; fertilizers [f]; bacteria
Residential Sources	
Common household maintenance and hobbies	*Common household products* [h]: Household cleaners; oven cleaners; drain cleaners; toilet cleaners; disinfectants; metal polishes; jewelry cleaners; shoe polishes; synthetic detergents; bleach; laundry soil and stain removers; spot removers and dry cleaning fluid; solvents; lye or caustic soda; household pesticides [i]; photographic chemicals; printing ink; other common products
	Wall and furniture treatments: Paints; varnishes; stains; dyes; wood preservatives (creosote); paint and lacquer thinners; paint and varnish removers and deglossers; paint brush cleaners; floor and furniture strippers

Source	Health, Environmental, or Aesthetic Contaminant [a, b, c]
Common household maintenance and hobbies (cont.)	*Mechanical repair and other maintenance products*: Automotive wastes [g]; waste oils; diesel fuel; kerosene; #2 heating oil; grease; degreasers for driveways and garages; metal degreasers; asphalt and roofing tar; tar removers; lubricants; rust proofers; car wash detergents; car waxes and polishes; rock salt; refrigerants
Lawns and gardens	Fertilizers [e]; herbicides and other pesticides used for lawn and garden maintenance [j]
Septic systems, cesspools, and sewer lines	Septage; coliform and noncoliform bacteria [d]; viruses; nitrate; heavy metals; synthetic detergents; cooking and motor oils; bleach; pesticides [i, j]; paints; paint thinner; photographic chemicals; septic tank/cesspool cleaner chemicals [k]; elevated levels of chloride, sulfate, calcium, magnesium, potassium, and phosphate
Underground storage tanks	Home heating oil
Municipal Sources	
Schools and government offices and grounds	Solvents; pesticides [i, j]; acids; alkalis; waste oils; machinery/ vehicle servicing wastes; gasoline and heating oil from storage tanks; general building wastes [l]
Park lands	Fertilizers [f]; herbicides [j]; insecticides [i]
Public and residential areas infested with mosquitoes, gypsy moths, ticks, ants, or other pests	Pesticides [e, i]
Highways, road maintenance depots, and deicing operations	Herbicides in highway rights-of-way [e, j]; road salt (sodium and calcium chloride); road salt anticaking additives (ferric ferrocyanide, sodium ferrocyanide); road salt anticorrosives (phosphate and chromate); automotive wastes
Municipal sewage treatment plants, sewer lines, disposal ponds, lagoons, and other surface impoundments	Sewage wastewater; sludge [m]; treatment chemicals [n]; nitrate; other liquid wastes; microbial contaminants
Land areas applied with wastewater or wastewater byproducts	Organic matter; nitrate; inorganic salts; heavy metals; coliform and noncoliform bacteria [d]; viruses; nitrate; sludge [m]; nonhazardous wastes [o]
Storm water drains and basins	Urban runoff; gasoline; oil; other petroleum products; road salt; microbial contaminants

Table 1. Potential Sources of Ground-Water Contamination

Source	Health, Environmental, or Aesthetic Contaminant [a, b, c]
Combined sewer overflows (municipal sewers and storm water drains)	Municipal wastewater; sludge [m]; treatment chemicals [n]; urban runoff; gasoline; oil; other petroleum products; road salt; microbial contaminants
Recycling/reduction facilities	Residential and commercial solid waste residues
Municipal waste landfills	Leachate; organic and inorganic chemicals; wastes from households [h] and businesses [l]; nitrates; oils; metals; microbial contaminants
Open dumping and burning sites, closed dumps	Leachate; organic and inorganic chemicals; metals; oils; wastes from households [h] and businesses [l]; microbial contaminants
Municipal incinerators	Heavy metals; hydrocarbons; formaldehyde; methane; ethane; ethylene; acetylene; sulfur and nitrogen compounds
Water supply wells, monitoring wells, older wells, domestic and livestock wells, unsealed and abandoned wells, and test hole wells	Surface runoff; effluents from barnyards, feedlots, septic tanks, or cesspools; gasoline; used motor oil; road salt
Sumps and dry wells	Storm water runoff; spilled liquids; used oil; antifreeze; gasoline; other petroleum products; road salt; pesticides [e]; and a wide variety of other substances
Well pumping that causes interaquifer leakage, induced infiltration	Excessively mineralized water
Artificial ground-water recharge	Storm water runoff; excess irrigation water; stream flow; cooling water; treated sewage effluent; other substances that may contain contaminants, such as nitrate, metals, detergents, synthetic organic compounds, bacteria, and viruses
Commercial Sources	
Auto repair shops	Waste oils, solvents, acids, paints, automatic wastes [g], miscellaneous cutting oils
Car washes	Soaps; detergents; waxes; miscellaneous chemicals
Camp grounds	Septage; gasoline; diesel fuel; pesticides for controlling insects and other pests [e, i]; household hazardous wastes from recreational vehicles (RVs) [h]
Cemeteries	Leachate; lawn and garden maintenance chemicals [j]

Table 1. Potential Sources of Ground-Water Contamination

Source	Health, Environmental, or Aesthetic Contaminant [a, b, c]
Construction trade areas and materials (plumbing, heating and air conditioning, painting, drywall and plastering, insulation, carpentry, flooring, roofing and sheet metal, wrecking and demolition, etc.)	Solvents; asbestos; paints; glues and other adhesives; waste insulation; lacquers; tars; sealants; epoxy waste; miscellaneous chemical wastes
Furniture repair and finishing shops	Paints; solvents; strippers; degreasing and solvent recovery sludges
Gasoline service stations	Gasoline; diesel; oils; solvents; miscellaneous wastes
Hardware/lumber/parts stores	Hazardous chemical products in inventories; heating oil and motor fuel from storage tanks; wood-staining and treating products such as creosote
Heating oil companies, underground storage tanks	Heating oil; wastes from truck maintenance areas [g]
Horticultural practices, garden nurseries, florists	Nitrate, phosphate, herbicides, insecticides, fungicides, and other pesticides [j]
Jewelry/metal plating shops	Sodium and hydrogen cyanide; metallic salts; hydrochloric acid; sulfuric acid; chromic acid
Laundromats	Detergents; bleaches; fabric dyes
Medical institutions	X-ray developers and fixers [p]; radiological wastes; biological wastes; disinfectants; asbestos; beryllium; dental acids; miscellaneous chemicals
Office buildings and office complexes	Building wastes [l]; lawn and garden maintenance chemicals [j]; gasoline; motor oil
Paint stores	Paints; paint thinners; lacquers; varnishes; other wood treatments
Print shops	Solvents; inks; dyes; oils; photographic chemicals
Railroad tracks and yards	Diesel fuel; herbicides for rights-of-way; creosote for preserving wood ties; solvents; paints; asbestos; metals
Scrap and junk yards	Any wastes from businesses [l] and households [h]; oils
Aboveground and underground storage tanks	Heating oil; diesel fuel; gasoline; other petroleum products; other commercially used chemicals
Transportation services for passenger transit (local and interurban)	Waste oil; solvents; gasoline and diesel fuel; fuel oil; other automotive wastes [g]

Table 1. Potential Sources of Ground-Water Contamination

Source	Health, Environmental, or Aesthetic Contaminant [a, b, c]
Veterinary services	Solvents; infectious materials; vaccines; drugs; disinfectants (quaternary ammonia, hexachlorophene, peroxides, chlornexade, bleach); x-ray developers and fixers [p]
Industrial Sources	
Material stockpiles (coal, metallic ores, phosphate, gypsum)	Acid drainage; other hazardous and nonhazardous wastes [o]
Tailing ponds (commonly for the disposal of mining wastes)	Acids; metals; dissolved solids; radioactive ores; sulfate; nitrate; other hazardous and nonhazardous wastes [o]
Transport and transfer stations (trucking terminals and rail yards)	Fuel tanks; repair shop wastes [g]; other hazardous and nonhazardous wastes [o]
Aboveground and underground storage tanks and containers	Heating oil; diesel and gasoline fuel; chlorinated solvents; other petroleum products; hazardous and nonhazardous materials and wastes [o]
Storage, treatment, and disposal ponds, lagoons, and other surface impoundments	Hazardous and nonhazardous liquid wastes [o]; septage; sludge [m]
Chemical landfills	Leachate; hazardous and nonhazardous wastes [o]; nitrate
Radioactive waste disposal sites	Radioactive wastes from medical facilities, power plants, and defense operations; radionuclides
Operating and abandoned production and exploratory wells (for gas, oil, coal, geothermal, and heat recovery); test hole wells; monitoring and excavation wells	Metals; hydrocarbons; acids; saline water; sulfides; other hazardous and nonhazardous chemicals [o]
Injection wells	Highly toxic wastes; hazardous and nonhazardous industrial wastes [o]; oil-field brines
Well drilling operations	Brines associated with oil and gas operations
Industrial processes (presently operated or historical facilities)	
Furniture and fixtures manufacturers	Paints; solvents; degreasing sludges; solvent recovery sludges
Machine and metalworking shops	Solvents; metals; miscellaneous organics; oily metal shavings; lubricating and cutting oils; degreasers; chlorinated solvents

Table 1. Potential Sources of Ground-Water Contamination

Source	Health, Environmental, or Aesthetic Contaminant [a, b, c]
Mining operations (surface and underground)	Mine spoils or tailings that often contain metals; acids; highly corrosive mineralized waters; metal sulfides; sulfate; salinity
Unsealed abandoned mines used as waste pits	Metals; acids; minerals; sulfides; other hazardous and nonhazardous chemicals [o]
Petroleum production and storage companies, secondary recovery of petroleum	Hydrocarbons; oil-field brines (highly mineralized salt solutions)
Industrial pipelines	Corrosive fluids; hydrocarbons; other hazardous and nonhazardous materials and wastes [o]
Publishers, printers, and allied industries	Solvents; inks; dyes; oils; miscellaneous organics; photographic chemicals
Public utilities (phone, electric power, gas)	PCBs from transformers and capacitors; oils; solvents; sludges; acid solution; metal plating solutions (chromium, nickel, cadmium); herbicides from utility rights-of-way
Sawmills and planers	Treated wood residue (copper quinolate, mercury); paint sludges; solvents; creosote; coating and gluing wastes
Stone, clay, and glass manufacturers	Solvents; oils and grease; alkalis; acetic wastes; asbestos; heavy metal sludges; phenolic solids or sludges; metal-finishing sludge
Welding facilities	Oxygen; acetylene; metals; paints; solvents
Wood preserving facilities	Wood preservatives; creosote

Source: Modified from EPA, February 1993.

[a] In general, ground-water contamination stems from the *misuse and improper disposal* of liquid and solid wastes; the *illegal dumping or abandonment* of household, commercial, or industrial chemicals; the *accidental spilling* of chemicals from trucks, railways, aircraft, handling facilities, and storage tanks; or the *improper siting, design, construction, operation, or maintenance* of agricultural, residential, municipal, commercial, and industrial drinking water wells and liquid and solid waste disposal facilities. Contaminants also can stem from *atmospheric pollutants*, such as airborne sulfur and nitrogen compounds, which are created by smoke, flue dust, aerosols, and automobile emissions, fall as acid rain, and percolate through the soil. When the sources listed in this table are used and managed properly, ground-water contamination is not likely to occur.

[b] Contaminants can reach ground water from activities occurring on the land surface, such as industrial waste storage, from sources below the land surface but above the water table, such as septic systems, from structures beneath the water table, such as wells, or from contaminated recharge water.

[c] This table lists the most common wastes, but not all potential wastes. For example, it is not possible to list all potential contaminants contained in storm water runoff.

[d] Coliform bacteria can indicate the presence of pathogenic (disease-causing) microorganisms that may be transmitted in human feces. Diseases such as typhoid fever, hepatitis, cholera, diarrhea, and dysentery can result from sewage contamination of water supplies.

[e] Pesticides include herbicides, insecticides, rodenticides, fungicides, and avicides. EPA has registered approximately 50,000 different pesticide products for use in the United States. Many are highly toxic and quite mobile in the subsurface. An EPA survey found that the most common pesticides found in drinking water wells were DCPA (dacthal) and atrazine, which EPA classifies as *moderately toxic* (class 3) and *slightly toxic* (class 4) materials, respectively.

[f] The EPA National Pesticides Survey found that the use of fertilizers correlates to nitrate contamination of ground water supplies.

[g] Automotive wastes can include gasoline, antifreeze, automatic transmission fluid, battery (sulfuric) acid, engine and radiator flushes, engine and metal degreasers, hydraulic (brake) fluid, and motor oils.

[h] Toxic or hazardous components of common household products are noted in EPA, 1993.

[i] Common household pesticides for controlling pests such as ants, termites, bees, wasps, flies, cockroaches, silverfish, mites, ticks, fleas, worms, rats, and mice can contain active ingredients including napthalene, phosphorus, xylene, chloroform, heavy metals, chlorinated hydrocarbons, arsenic, strychnine, kerosene, nitrosamines, and dioxin.

[j] Common pesticides used for lawn and garden maintenance (i.e., weed killers, and mite, grub, and aphid controls) include such chemicals as 2,4-D, chlorpyrifos, diazinon, benomyl, captan, dicofol, and methoxychlor.

[k] Septic tank/cesspool cleaners include synthetic organic chemicals such as 1,1,1-trichloroethane, tetrachloroethylene, carbon tetrachloride, and methylene chloride.

[l] Common wastes from public and commercial buildings include automotive wastes, rock salt, and residues from cleaning products that may contain chemicals such as xylenols, glycol esters, isopropanol, 1,1,1-trichloroethane, sulfonates, chlorinated phenolys, and creosols.

[m] Municipal wastewater treatment sludge can contain organic matter, nitrate, inorganic salts, heavy metals, coliform and noncoliform bacteria, and viruses.

[n] Municipal wastewater treatment chemicals include calcium oxide, alum, activated alum, carbon, and silica, polymers, ion exchange resins, sodium hydroxide, chlorine, ozone, and corrosion inhibitors.

[o] The Resource Conservation and Recovery Act (RCRA) defines a hazardous waste as a solid waste that may cause an increase in mortality or serious illness or pose a substantial threat to human health and the environment when improperly treated, stored, transported, disposed of, or otherwise managed. A waste is hazardous if it exhibits characteristics of ignitability, corrosivity, reactivity, and/or toxicity. Not covered by RCRA regulations are domestic sewage, irrigation waters or industrial discharges allowed by the Clean Water Act, certain nuclear and mining wastes, household wastes, agricultural wastes (excluding some pesticides), and small quantity hazardous wastes (i.e., less than 220 pounds per month) generated by businesses.

[p] X-ray developers and fixers may contain reclaimable silver, glutaldehyde, hydroquinone, phenedone, potassium bromide, sodium sulfite, sodium carbonate, thiosulfates, and potassium alum.

Table 2. Principal Sources of Contamination on the Hopi Reservation

Source	Potential Contaminant(s)
Septic tanks	Nitrate, bacteria, viruses
Sewage lagoons	Nitrate, bacteria, viruses
Peabody coal mine	Sulfate, metals
Tuba City UMTRA site	Uranium, sulfate, nitrate, metals
Other abandoned mines	Acids, metals, sulfate, salinity
Landfills*	Hydrocarbons, miscellaneous
Livestock	Nitrate, bacteria, viruses
Underground storage tanks	Motor fuels, miscellaneous hydrocarbons
Irrigation	Increased salinity

* The new Hopi landfill was constructed in a lined cell with a ground-water monitoring program; abandoned landfills are a much greater threat to water supplies.

Regulatory controls include zoning ordinances, subdivision ordinances, and design and construction standards. Additional regulatory controls include ground-water monitoring and compliance with Tribal and/or federal water quality standards. Summaries of federal maximum contaminant levels for drinking water are shown in Tables 3 through 5. Nonregulatory controls include public education, purchase of land within the WHPAs, ground-water monitoring, and household hazardous waste collection programs. Of these, public education and the implementation of a household hazardous waste collection program are likely to be important issues for Hopi wellhead protection.

Implementation issues must also be addressed in developing a wellhead protection program. For example, legal issues, such as the need to establish a Tribal Wellhead Protection Ordinance, should be examined. Also, potential funding sources, such as U.S. EPA grants, should be sought.

Table 3. Federal Regulatory Standards for Metals and Major Ions

Compound	Regulatory Status [a]	Regulatory Standard (mg/L)				Cancer Group [b]
		SMCL	MCLG	MCL	DWEL	
Metals						
Al	F	0	---	---	---	---
Sb	F	---	0	0	0	D
As	T	---	---	0	---	A
Ba	F	---	2	2	2	D
Be	F	---	0	0	0	B2
Cd	F	---	0	0	0	D
Cr	F	---	0	0	0	D
Cu	F	1	1	TT	---	D
Pb	F	---		0	---	B2
Mn	F	0	---	---	---	---
Mo	L	---	---	---	0	D
Ni	F	---	0	0	1	D
Se	F	---	0	0	---	---
Ag	F	0	---	---	0	D
Tl	F	---	0.0005	0	0.0023	---
U	P	---		0	---	A
V	T	---	---	---	---	D
Zn	F	5	---	---	10	D
Major Ions						
NO_3+NO_2-N	F	---	10	10	---	---
NH_3-N	---	---	---	---	---	D
Cl	F	250	---	---	---	---
SO_4	F	250	500 P	500 P	---	---
TDS	F	500	---	---	---	---

SMCL = Secondary Maximum Contaminant Level: A concentration, based on the aesthetic quality of the water (such as taste, odor, or color), above which the water may not be pleasant to drink, but which will not cause health problems.

MCLG = Maximum Contaminant level Goal: A non-enforceable concentration of a drinking water contaminant that is protective of adverse human health effects and allows an adequate margin of safety.

MCL = Maximum Contaminant Levels: Maximum permissible level of a contaminant in water which is delivered to any user of a public water system.

DWEL = Drinking Water Equivalent Level: A lifetime exposure concentration protective of adverse, non-cancer health effects that assumes all of the exposure to a contaminant is from a drinking water source.

TT = Treatment technique

[a] F = Final
P = Proposed
T = Tentative (not officially proposed)
L = Listed for regulation

[b] A = Human carcinogen
B = Probable carcinogen based on epidemiological studies (B1) or based on animal studies (B2)
C = Possible human carcinogen
D = Not classifiable

Table. 4. Federal Regulatory Standards for Herbicides, Pesticides, and Semivolatile Organic Compounds

Compound	Regulatory Status [a]	Regulatory Standard (mg/L)			Cancer Group [b]
		MCLG	MCL	DWEL	
Acid Herbicides					
2,4,5---T	L	---	---	350	---
2,4,5---TP (Silvex)	F	50	50	50	---
2,4---D	F	70	70	400	---
Bentazon	T	20	---	90	D
Chloramben	---	---	---	500	D
Dacthal (DCPA)	L	---	---	20000	D
Dalapon	F	200	200	900	D
Dicamba	L	---	---	1000	D
Dinoseb	F	7	7	40	D
Pentachlorophenol (PCP)	F		1	1	B2
Picloram	F	500	500	2000	D
Carbamate Pesticides					
Aldicarb	D	7	7	35	D
Aldicarb Sulfone	D	7	7	35	D
Aldicarb Sulfoxide	D	7	7	35	D
Baygon (Propoxur)	---	---	---	100	C
Carbaryl (Sevin)	---	---	---	4000	D
Carbofuran (Evradan)	F	40	40	200	E
Methomyl	L	---	---	900	D
Oxamyl	F	200	200	900	E
Glyphosate	F	700	700	4000	E
Semivolatile Organic Compounds					
Acenapthylene	---	---	---	---	---
Alachlor	F		2	400	---
Aldrin	---	---	---	1	B2
Aroclor 1221 (PCB)	F		0.5	---	B2
Aroclor 1232	F		0.5	---	B2
Aroclor 1242/1016	F		0.5	---	B2
Aroclor 1248	F		0.5	---	B2
Aroclor 1254	F		0.5	---	B2
Aroclor 1260	F		0.5	---	B2
Atrazine	F	3	3	200	C
Benzo(a)anthracene	---	---	---	---	B2
Benzo(b)fluoranthene	---	---	---	---	B2
Benzo(ghi)perylene	---	---	---	---	D
Benzo(k)fluoranthene	---	---	---	---	B2
Benzo[a]pyrene	F		0.2	---	B2
Bromacil	L	---	---	5000	C
Chlordane (Total)	F		2	2	B2
Chlorothalonil (Daconil)	---	---	---	500	B2

Table. 4. Federal Regulatory Standards for Herbicides, Pesticides, and Semivolatile Organic Compounds

Compound	Regulatory Status [a]	Regulatory Standard (mg/L)			Cancer Group [b]
		MCLG	MCL	DWEL	
Chlorpyrifos (Dursban)	---	---	---	100	D
Chrysene	---	---	---	---	B2
Cyanazine	T	1	---	70	C
Di(2-ethylhexyl)adipate	F	400	400	20000	C
Di(2-ethylhexyl)phthalate	F		6	700	B2
Dibutylphthalate	---	---	---	4000	D
Dieldren	---	---	---	2	B2
Dimethylphthalate	---	---	---	---	D
Endrin	F	2	2	10	D
Fluorene	---	---	---	---	D
Heptachlor	F		0.4	20	B2
Heptachlor epoxide	F		0.2	0.4	B2
Hexachlorobenzene	F		1	30	B2
Hexachlorocyclopentadiene	F	50	50	200	D
Indeno(1,2,3,cd)pyrene	---	---	---	---	B2
Lindane	F	0.2	0.2	10	C
Malathion	---	---	---	800	D
Methoxychlor	F	40	40	40	D
Metolachlor	L	---	---	3500	C
Metribuzin	L	---	---	500	D
Pentachlorophenol	F		1	1000	B2
Phenanthrene	---	---	---	---	---
Propachlor (Ramrod)	---	---	---	500	D
Propazine	---	---	---	700	C
Pyrene	---	---	---	---	D
Simazine	F	4	4	200	C
Tebuthiuron	---	---	---	2000	D
Terbacil	---	---	---	400	E
Toxaphene	F		3	---	B2
Trifluralin	L	---	---	300	C

MCLG = Maximum Contaminant level Goal: A non-enforceable concentration of a drinking water contaminant that is protective of adverse human health effects and allows an adequate margin of safety.

MCL = Maximum Contaminant Levels: Maximum permissible level of a contaminant in water which is delivered to any user of a public water system.

DWEL = Drinking Water Equivalent Level: A lifetime exposure concentration protective of adverse, non-cancer health effects that assumes all of the exposure to a contaminant is from a drinking water source.

ND = Not detected

[a] F = Final
D = Draft
P = Proposed
T = Tentative (not officially proposed)
L = Listed for regulation

[b] A = Human carcinogen
B = Probable carcinogen based on epidemiological studies (B1) or based on animal studies (B2)
C = Possible human carcinogen
D = Not classifiable
E = No evidence of carcinogenicity for humans

Table 5. Federal Regulatory Standards for Volatile Organic Compounds

Compound	Regulatory Status [a]	Regulatory Standard (mg/L)			Cancer Group [b]
		MCLG	MCL	DWEL	
Benzene	F	0	5	-	A
Bromobenzene	L	-	-	-	-
Bromodichloromethane	P	0	80	700	B2
Bromoform	P	0	80	700	B2
Bromomethane	T	-	-	40	D
Carbon tetrachloride	F	0	5	30	B2
Chlorobenzene (monochlorobenzene)	F	100	100	700	D
Chloroethane	L	-	-	-	B
Chloroform	P	0	80	400	B2
Chloromethane	L	-	-	100	C
1,2-Dibromo-3-chloropropane (DBCP)	F	0	0.2	-	B2
1,2-Dibromoethane (EDB)	F	0	0.05	-	B2
Dibromomethane	L	-	-	-	D
1,2-Dichlorobenzene (o-Dichlorobenzene)	F	600	600	3000	D
1,3-Dichchlorobenzene (m-Dichlorobenzene)	-	-	-	3000	D
1,4-Dichlorobenzene (p-Dichlorobenzene)	F	75	75	4000	C
Dichlorodifluoromethane	L	-	-	5000	D
1,2-Dichloroethane	F	0	5	-	B2
1,1-Dichloroethene	F	7	7	400	C
cis-1,2-Dichloroethene	F	70	70	400	D
trans-1,2-Dichloroethene	F	100	100	600	D
1,2-Dichloropropane	F	0	5	-	B2
1,3-Dichloropropane	L	-	-	-	-
2,2-Dichloropropane	L	-	-	-	-
1,1-Dichloropropene	L	-	-	-	-
Ethylbenzene	F	700	700	3000	D
Hexachlorobutadiene	T	1	-	70	C
Methylene chloride (Dichloromethane)	F	0	5	2000	B2
Napthalene	-	-	-	100	D
Styrene	F	100	100	7000	C
1,1,1,2-Tetrachloroethane	L	-	-	1000	C
1,1,2,2-Tetrachloroethane	L	-	-	-	-
Tetrachloroethene	F	0	5	5000	-
Toluene	F	1000	1000	7000	D
1,2,4-Trichlorobenzene	F	70	70	40	D
1,1,1-Trichloroethane	F	200	200	1000	D
1,1,2-Trichloroethane	F	3	5	100	C
Trichloroethene	F	0	5	300	B2

Table 5. Federal Regulatory Standards for Volatile Organic Compounds

Compound	Regulatory Status [a]	Regulatory Standard (mg/L)			Cancer Group [b]
		MCLG	MCL	DWEL	
1,2,3-Trichloropropane	L	-	-	200	B2
Vinyl chloride	F	0	2	-	A
Total Xylenes	F	10,000	10,000	60,000	D

MCLG = Maximum Contaminant level Goal: A non-enforceable concentration of a drinking water contaminant that is protective of adverse human health effects and allows an adequate margin of safety.
MCL = Maximum Contaminant Levels: Maximum permissible level of a contaminant in water which is delivered to any user of a public water system.
DWEL = Drinking Water Equivalent Level: A lifetime exposure concentration protective of adverse, non-cancer health effects that assumes all of the exposure to a contaminant is from a drinking water source.
ND = Not detected

[a] F = Final
L = Listed for regulation
P = Proposed
T = Tentative (not officially proposed)

[b] A=Human carcinogen
B=Probable carcinogen based on epidemiological studies (B1) or based on animal studies (B2)
C=Possible human carcinogen
D=Not classifiable

2.5 Plan for the Future

The wellhead protection program must continue into the future to ensure protection of the water resources. The community planning team must plan for future water needs and plan to reassess the WHPAs and overall effectiveness of the program. Planning for the future also includes developing contingency plans should a well or well field become contaminated. The contingency plan may include an alternative water supply and emergency response procedures.

The community planning team should consult with the Hopi Tribe Office of Research and Planning and the Hopi Village leaders regarding the potential for development of new water supply wells.

3. GENERAL GUIDANCE ON DEFINING WELLHEAD PROTECTION AREAS

The wellhead protection areas (WHPAs) can be defined by drawing a specified radius around each well, or they can be defined in a more rigorous manner by using computer ground-water flow models. Knowledge of contaminant transport and hydrologic properties is essential for developing WHPAs. For instance, heavy metals and viruses are not very mobile in clay-rich aquifer material, but they could migrate much farther in a fractured limestone or sandstone aquifer. Concepts such as the zone of influence (ZOI) and the zone of contribution (ZOC) must also be understood. The ZOI is the area throughout which pumping from a well causes drawdown within the aquifer. The ZOC is that portion of the aquifer that supplies water to the well, which includes a large part of the ZOI, but not the entire area.

The EPA presents the following five criteria that can be used in combination with nontechnical considerations (for example, administrative) to form the technical basis for WHPA delineation (EPA, 1987a):

- Distance
- Drawdown
- Time of travel
- Flow boundaries
- Assimilative capacity

These conceptual standards form the basis for WHPA delineation, which is summarized in the following paragraphs.

The *distance* criterion is the concept of assigning a specific radius (or other dimension) around the well. This method is often a first step in WHPA delineation. The WHPAs can be further refined if a more rigorous technical approach can be applied. Although this criterion has the advantage of simplicity, it does not directly incorporate the processes of ground-water flow or contaminant transport. Table 6 presents distance criteria adopted by a variety of governmental entities in defining WHPAs.

Table 6. Distances Used to Define Wellhead Protection Area

Community	Distance (ft)
City of Santa Fe, NM	1,000
Louisiana	5,280
Nevada	3,000
New Mexico	1,000
Edgartown, MA	2,500
Pennsylvania	1,320 to 5,280
Nebraska	1,000
West Germany	6,563 (2 km)

The radius (r) can be calculated by using the following equation (EPA, 1987a):

$$r = \sqrt{\frac{Q * t}{\pi * n * H}}$$

Where Q = Pumping rate of well (ft^3 per year)
n = Aquifer porosity (dimensionless) (typically 15 to 30 percent for the Hopi aquifers)
H = Open interval or length of well screen (ft)
t = Travel time to well (years), (as decided based on potential remedial time and contaminant source locations)
π = 3.1416

The *drawdown* criterion is based on the extent to which pumping a well will lower the water table of an unconfined aquifer or the potentiometric surface of a confined aquifer. The WHPA based on drawdown criteria would be the ZOI, which is the area underlying the cone of depression. The ZOI may be only a few tens of feet in shallow water table aquifers near a recharge source to tens of miles in confined consolidated regional aquifers. One disadvantage of the drawdown criterion is that it does not account for all areas that contribute flow to a well. For instance, in a highly productive shallow aquifer where the cone of depression would extend only a few tens of feet from the well, the travel time for water (with contamination) 200 feet away may be less than a few weeks or even days. Another disadvantage is that areas downgradient and cross-gradient to the well will fall within the WHPA, when in actuality these areas within the aquifer will not contribute water to the well.

When aquifer hydraulic properties are known, the dimensions of the cone of depression around a pumped well may often be calculated for a specified time period using simple analytical solutions and reviewing the existing water level data. A threshold for the amount of drawdown that defines the cone of depression must be selected. Drawdown values between 0.1 and 1 foot are typically within the range considered. For example, Dade County, Florida used a threshold of 0.25 feet to define the cone of depression, which resulted in a WHPA distance of 23,000 feet. Palm Beach, Florida used a drawdown threshold of 1 foot, which resulted in a WHPA distance of 10,500 feet. Similarly, a radius could be calculated for Hopi wells, given site-specific aquifer properties and a selected threshold value.

The *time of travel* (TOT) criterion for WHPA delineation is based on the maximum time for a ground-water contaminant to reach a well after it is released. This criterion incorporates a more comprehensive evaluation of the physical processes of contaminant transport and typically includes the time for a surface contaminant to migrate to ground water and subsequently to a well. The TOT may be calculated through analytical solutions or more complex numerical modeling.

The TOT criterion usually ranges between 5 and 50 years, except in high-flow settings where the TOT criterion is less than 5 years (EPA, 1987a). Table 7 summarizes the TOT compiled by EPA and DBS&A. As discussed in Section 2, due to the depth (>1,500 feet) of the Hopi community water supply wells and the presence of one or more confining layers, TOTs through natural formations beneath the Hopi land will typically be very great. The TOT criteria is more applicable to near-surface Hopi springs and in the unconfined N-aquifer at Moencopi.

Flow boundaries can be used as a criterion for delineating WHPAs, particularly when the aquifer is small or the well is located close to a hydrologic boundary. Hydrologic boundaries (such as rivers, faults, mountains, or ridges) influence the zone of capture for a well. This criterion may be used in concert with other criteria. For instance, if a WHPA is delineated based on a fixed

Table 7. Summary of TOTs Compiled by EPA and DBS&A

Time of Travel	Location	Maximum WHPA Distance (ft)
15 years	Santa Fe, NM	---
1 year	Nevada	---
50 days	Southern England	8,200
25 years	The Netherlands	3,920
100 to 210 days	Dade County, FL	5,300 to 10,000
10 to 50 years	Falmouth, MA	2,500 to 12,500

radius of 1 mile, but the well is located one quarter of a mile from a gaining river, the WHPA may not extend to the other side of the river, since no ground-water flow will occur across the river.

The *assimilative capacity* of the aquifer can be used as a criterion for WHPA delineation. The assimilative capacity of a formation is its capacity to lessen the concentration of contaminants to acceptable levels before they reach a well. Factors that may affect contaminant concentrations are dilution, soil and aquifer matrix composition and conditions (particularly the amount of organic matter contained in the aquifer), and the type of contaminant. This analysis is the most complex approach to delineating WHPAs. It may be appropriate where one type of contamination is the only threat in the vicinity of a well, such as a particular pesticide used on a crop.

4. SUMMARY

The process of developing a wellhead protection program requires a commitment by the Hopi community to protect its water resources. This commitment will require forming a community planning team that will formulate the goals and objectives of the wellhead protection program and will work with technical advisors to obtain those objectives. Technical expertise is required to assess the hydrogeology and contaminant properties and to delineate the appropriate areas to protect. The wellhead protection program must also continue into the future to reassess the protected areas and to develop contingency plans.

The primary issues to be addressed by the community planning team include defining the method used to delineate WHPAs, determining how to address existing sources within the delineated WHPAs and identifying the most feasible implementation measures. The principal areas of concern for the Hopi wellhead protection program are the unconfined N-aquifer in the Moencopi area and springs emanating from the near-surface Toreva and Wepo Formations. Provisions for prevention of contamination through wellbores in confined water supply wells is also an important issue to be addressed by the Hopi wellhead protection program.

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