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Delineating Surface Water Sources and Protection Zones

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This booklet is part of a series of educational brochures and slide sets that focuses on various aspects of water source protection. The series has been prepared jointly by the University of California Agricultural Extension Service and the California Department of Health Services.

For further information about this and other documents in the series, contact the project team leader (see below) or visit the following website:

www.dhs.ca.gov/ps/ddwem/dwsap/DWSAPindex.htm

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Cover photo: Pyramid Lake, one of many reservoirs in the State Water Project, delivers water to Los Angeles and other southern California coastal cities

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For the purposes of California's Drinking Water Source Assessment and Protection (DWSAP) Program, the *source area* for a surface water body is defined as the combined watershed of all the tributaries to the water intake. This is consistent with the definition of source area provided in the California Code of Regulations, Title 22, Chapter 17, Section 64665, which requires public water systems that rely on surface water to conduct watershed sanitary surveys.

A *watershed* is an area of land that drains to a single outlet and is separated from other watersheds by a *divide* (Haan *et al.*, 1994). Watersheds can be identified and delineated by examining a printed topographic map or by analyzing digital elevation data with a geographic information system (GIS). Both of these methods require practice and careful review to make sure that the delineation of divides and watersheds is accurate.

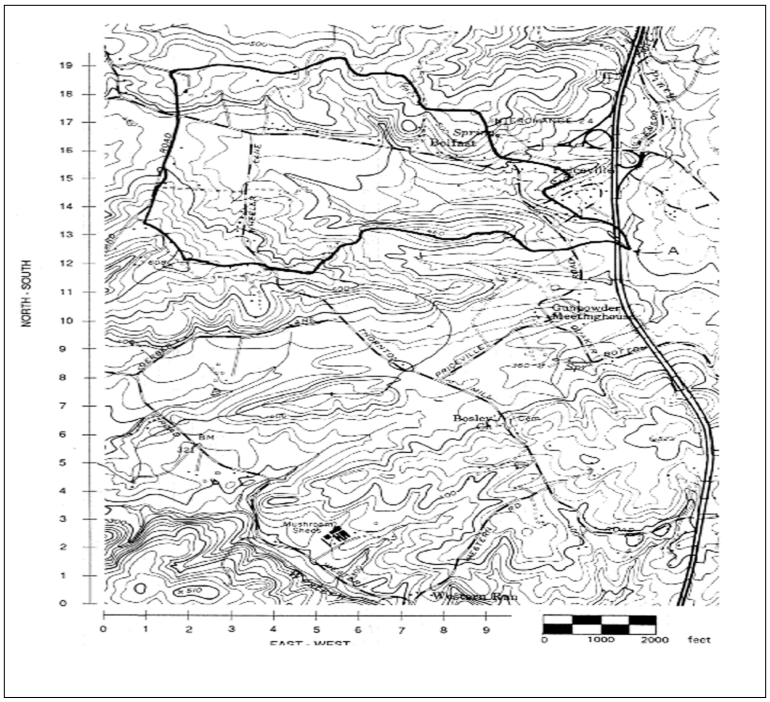

Figure 1. Delineation of watershed on a topographic map (McCuen, 1989).

The best type of map for basin delineation is the USGS 7.5-minute (1:24,000 scale) topographic map. A sample of such a map is shown in Figure 1. When delineating a watershed using a topographic map, the steps below should be followed:

1. Identify or approximate an outlet point.
2. Locate the ridge lines. Ridgelines are natural divides between watersheds.
3. Draw lines perpendicular to the contour lines that drain to the chosen outlet point.

Direct use of electronic or digital data is becoming commonplace in the field of hydrology. A GIS can help to speed up and automate the basin delineation process. Many formats of elevation data can be used to delineate a basin with the GIS. Some of these are: digital contours, triangle irregular networks (TIN), and digital elevation models (DEM). One of the easiest formats to obtain is the DEM; it uses a consistent cell size and is widely available from sources such as the USGS. When delineating watersheds with a GIS, follow these steps:

1. Compute the flow direction for each cell. Flow will be either into a cell or out of a cell, and the GIS assigns a value to each cell accordingly.
2. Calculate the flow accumulation for each cell. A cell with zero or near-zero flow accumulation (i.e., all water drains away from that cell) necessarily falls on a watershed divide. A cell with a high value of flow accumulation normally is located further down in the watershed, possibly within a stream channel.
3. Delineate the basin, using the flow direction to separate basins and the flow accumulation to indicate the outlets of a basin.
4. Generate a polygon or line coverage of the basin boundary and display graphically on a map.

The above instructions may require modification, depending on which GIS software package is being used and what the intended results are. When compared to delineating by hand, GIS software decreases the time required to delineate large watersheds. Using GIS can also help remove some of the error involved when delineating by hand. In addition, GIS software can easily be used to model other hydrologic parameters in a watershed.

Once they've identified their entire watershed boundary, managers of a public water system may conclude they also wish to establish one or more protection zones closer to the surface water intake. The purpose of such zones is to define portions of the watershed where activities have a higher risk of contaminating the water supply. The zones allow for well defined areas in which thorough evaluation of activities can maximize efforts to protect the source water.

Establishing zones can potentially reduce the effort involved in conducting source water assessments. For example, California's surface water treatment regulations require water purveyors to survey the entire watershed. If a water purveyor also establishes zones, DHS may allow a less detailed review on portions of

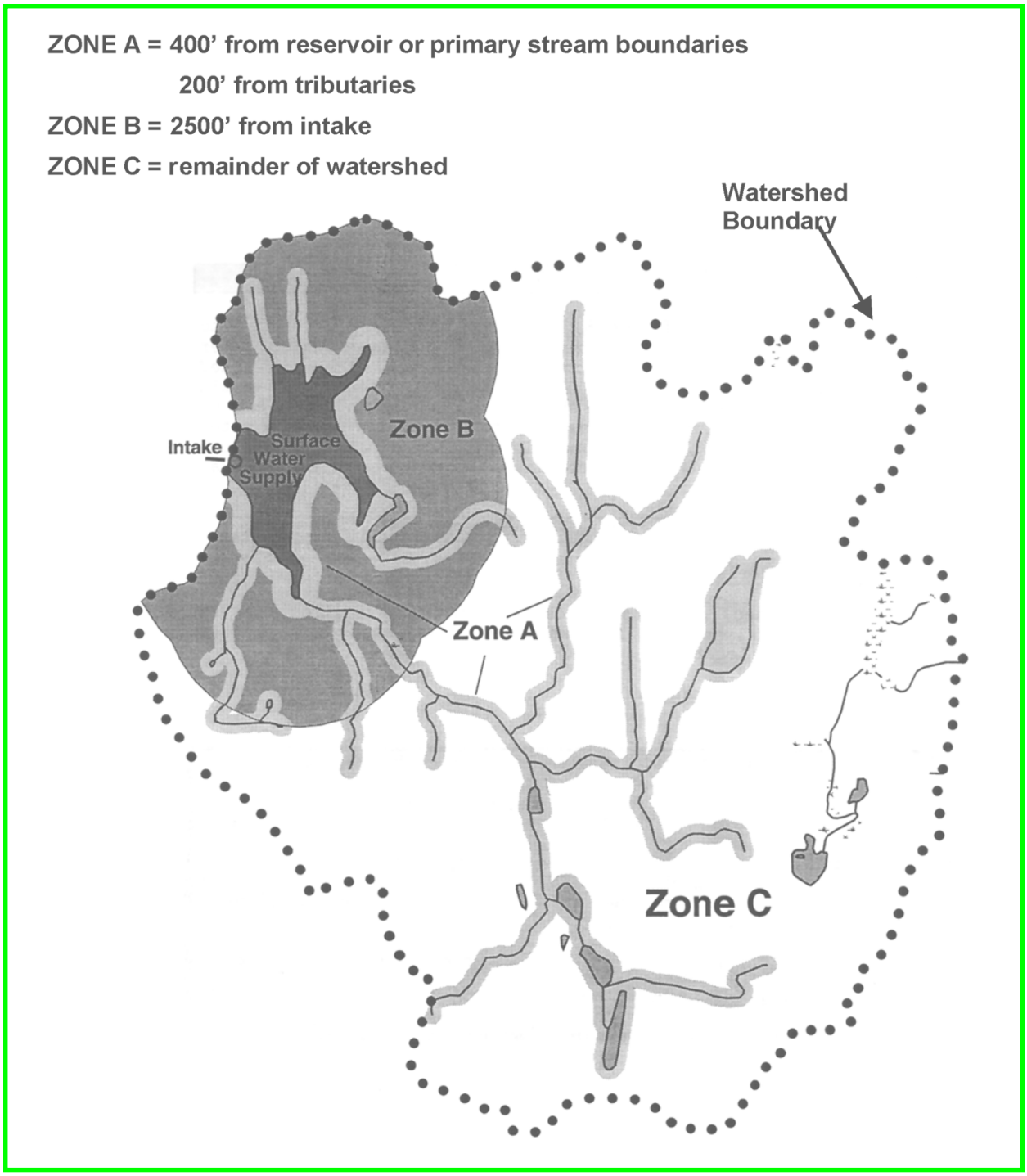

Figure 2. Surface water supply protection areas, showing suggested zones. Adapted from booklet entitled Developing a Local Surface Water Supply Protection Plan, published by Massachusetts Division of Environmental Protection in 1996.

the watershed outside the zones.In addition, when conducting the vulnerability analysis, possible contaminating activities (PCAs) located on the watershed, but outside of the zones, could be assigned less risk.(If zones have not been defined, PCAs are considered to be of equal risk, regardless of their location on the watershed.)

To establish zones for surface water sources of drinking water, a variety of methods may be used. These include:

- **Fixed Distance:** In this method, setbacks from reservoir boundaries, tributaries, and the intake are established by assigning fixed distances (Figure 2). While not technically sophisticated, this method is relatively simple to implement.
- **Time-of-Travel:** In this method, the protection zone is actually a stream reach, rather than an area. It is typically used for determining response times for spill events.The time-of-travel between an upstream

Table 1: How Some Other States Delineate Surface-Water Zones

State	Type of Surface Water	Segment or Zone	Method Used to Delineate Zones
Arizona	Rivers/canals	Segment A	500-foot buffer on each side, up to the next dam or state boundary or to the end of development
Arizona	Rivers/canals	Segment B	Remainder of watershed
Arizona	Lakes/reservoirs	Segment A	500-foot buffer around perimeter and upstream from intake to state boundary, next dam, or end of development
Arizona	Lakes/reservoirs	Segment B	Remainder of watershed
Nevada	Rivers	Zone A	500-foot buffer zone on each side for 10 miles upstream
Nevada	Rivers	Zone B	Remainder of watershed
Nevada	Lakes/reservoirs	Zone A	500 feet around perimeter
Nevada	Lakes/reservoirs	Zone B	3,000 feet outside Zone A
Ohio	All watersheds	*(not applicable)*	Watersheds are defined by using 8-digit, 11-digit, or 14-digit hydrologic units. The smallest hydrologic unit that includes the intake of interest is used.
Nebraska	All watersheds	*(not applicable)*	24-hour Time of Travel (T.O.T.) zone for each Watershed Delineation Area (W.D.A.) is individually determined by the state. This 24-hour T.O.T. zone is called the "Assessment Area." The Assessment Area is determined using high stream flow data (see the formula elsewhere on this page). The state also determines the 12-hour, 6-hour, and 3-hour T.O.T. zones within the Assessment Area. Regulatory agencies then determine the extent of the evaluation to be conducted in each zone.

monitoring point and the point of interest is calculated. Potential contaminants with a certain time-of-travel would be of primary concern.

- **Modeling:** Surface runoff and ground water discharge models can be used to assess the impact of individual contaminants from PCAs. They can also be used to identify the areas within the watershed that have greatest potential impact on the quality of the drinking water source.

If zones within the watershed are established for a surface water source, DHS suggests the following distances:

- 400 feet from reservoir or primary stream boundaries
- 200 feet from tributaries, and
- 2,500 feet from intakes.

A review of the Surface Water Zone Delineation methods used in other states provides some guidance when establishing setbacks and zone criteria. Refer to the examples for Arizona, Nevada, Nebraska, and Ohio in Table 1.

The following formula and information explains how the Assessment Area (24-hour TOT zone) is determined:

$$Dist(miles) = \left\{ \frac{V_k}{\sqrt{Flow_k / Flow_{90}}} \right\} \times \frac{86400\,sec/\,day}{5280\,ft\,/\,mile}$$

Dist (miles) = 24-hour Time of Travel distance in miles

V_k (feet/second) = velocity of stream; measured in the field by various agencies (USGS, NDEQ, Nebraska

Department of Water Resources, Nebraska Game and Parks Commission, etc.)

Flow$_k$ (cubic feet/second) = known flow of stream; calculated from stream velocity and stream length and depth (area), which was measured in the stream by various agencies (listed above)

Flow$_{90}$ (cubic feet/second) = calculated flow of stream at 90% of measured high flow, determined using many data measurements by various agencies (listed above)

Regardless of the method used, factors that may be considered in determining zones include topography (slopes), soils, geology, vegetation, precipitation, hydrology, and land uses. Establishment of zones, if done by public water systems or communities, should be done in consultation with California Department of Health Services (DHS).

Interested water suppliers, communities, or groups that require additional information may wish to refer to the EPA document, *State Methods for Delineating Source Water Protection Areas for Surface Water Supplied Sources of Drinking Water* (US EPA, 1997).

Ground water under the influence of surface water

For drinking water sources that have been classified as ground water under the *direct* influence of surface water (GWUDI), the source area should include the land area within the watershed boundaries. This is consistent with DHS regulations, because GWUDI wells are considered surface water sources and are subject to surface water treatment regulations. Zones for these sources may be established by ground water methods or surface water methods, or both, as appropriate.

For drinking water sources that are indirectly under the influence of surface water (*e.g.*, where the source of water is underflow from a surface water body and the source has not been classified as GWUDI), it is appropriate to include the land area within the watershed boundaries in the source area. The recharge area, if different from the watershed area, may also be included in the source area. For such situations, zones are to be established using ground water methods, as appropriate. The areas to be assessed should be determined in consultation with DHS.

Reference

- Haan, C. T., Barfield, B. J, and Hayes, J. C., (1994) *Design Hydrology and Sedimentology for Small Catchments*; Academic Press, San Diego, CA.