ESTIMATION OF RUSSIAN RIVER TRAVEL TIMES

WITH

PROPOSED SITING FOR TOXIC SUBSTANCE EARLY WARNING

IN THE RUSSIAN RIVER BASIN

[Prepared in partial fulfillment of the workplan, "Toxic Substances Detection and Early Warning for the Russian River", May 14, 1985.]

by

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ABSTRACT

A potential network of sites for early warning of chemical inputs to the Russian River, a major domestic water supply for Mendocino, Sonoma, and northern Marin counties, is proposed.

The potential sites are identified through information on the major public water supply diversions and zones of diversion, potential areas of input of hazardous and/or toxic chemicals, and travel time estimates for the river at various discharge rates.

The logic used to estimate travel times and to propose the potential sites using the above-mentioned information is presented. All relevant data are included in appendices to this report.

INTRODUCTION

This report fulfills Task 1 to the Section 205(j) project, "Toxic Substance Detection and Early Warning for the Russian River". The primary objective of that task was: "...to determine key river sites that could serve as early warning stations for major drinking water diversions along the entire Russian River" (NCRWQCB, 1985). Although the task dealing with testing such an early warning system is not yet completed, this report proposes sites that might be used in the event an early warning network is actually proposed. Of course, the establishment of a network of early warning sites must be accompanied by a system of notification. A task force composed of state and local governmental agencies with jurisdiction over domestic water use and the water purveyors would be responsible for developing such a system.

The Russian River basin has several important beneficial uses, the highest being the use as a drinking water supply for nearly 500,000 people. The municipal water systems provide limited, if any, off-stream storage and only minimal water treatment by chlorination. Many of these municipal diversions are Ranney collectors placed in or adjacent to the river, that draw upon the river underflow in the alluvial gravels. There is direct hydraulic continuity with river surface flows and these subsurface collectors.

The threat of uncontrolled or unknown toxic substance discharges and/or spills into the Russian River is of immense concern to the Regional Board, water purveyors, and residents of Mendocino, Sonoma, and northern Marin counties. This concern prompted the development of a workplan under the first cycle of 205(j) grant funding for a program to identify potential discharge sources within the basin (NCRWQCB, 1983). That program has been completed, and findings indicate that management practices on the storage, use, transport, and disposal of hazardous substances vary widely within the basin (NCRWQCB, 1987). Inspections conducted under the program have shown that many businesses utilize excellent practices and positive controls designed to prevent discharge to groundwaters or surface waters, while others have virtually no preventive measures. Some businesses inspected during the program were found to have illegal, direct discharges to surface waters or groundwater, and regulatory action was required. The threat of unwanted chemicals entering domestic water supplies adjacent to the Russian River is real.

This report details the methods used to arrive at a potential network of early warning stations for the Russian River basin. The network is based on knowledge of the locations of domestic water withdrawal, the use patterns and storage locations of hazardous and toxic chemicals, and estimated travel times in the Russian River.

DOMESTIC WATER USE

A necessary part of locating potential sites for early warning stations is the location of domestic water supplies. The Russian River basin supplies domestic water for nearly 500,000 residents of Mendocino, Sonoma, and northern Marin counties. Major domestic supplies (more than 200 connections) are regulated by the State Department of Health Services; those with under 200 connections are regulated by the county health departments.

Both state and county health departments provided information on the locations of major and minor domestic diversions. The thirty diversions identified were first located on a U.S. Geological Survey map, then those most likely to be influenced by the quality of the Russian River were identified by their proximity to the river. The county health departments identified known zones of diversion that are not directly regulated. Those zones are either areas where many diversions are located in a small area or areas along the river where domestic supplies are known to have existed historically and may now be in use. It is not known for certain in some zones if additional, unregulated use is occurring. The major diversions and/or zones of diversion for domestic use are identified in Figure 1.

Agricultural supplies are not identified since this report deals primarily with domestic supplies. The potential sites that are identified in this report could be used (and will be if a network is implemented) to protect agricultural supplies. In addition, the same process described in this report could be used for siting early warning stations for agricultural supplies, although their mobile nature and large number would make the process rather lengthy and difficult.

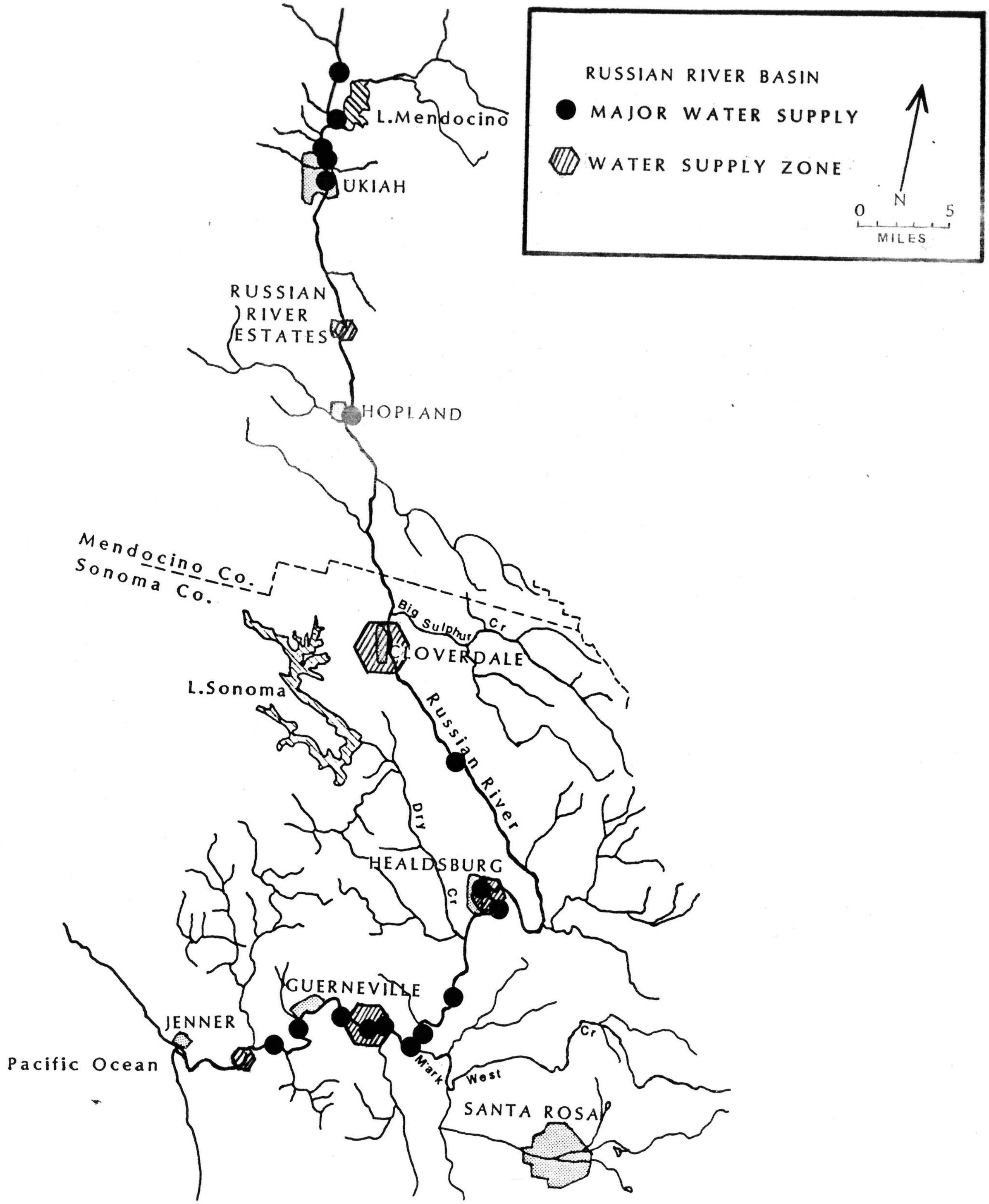

Figure 1. Relative locations of major water supplies (more than 200 connections) and general zones of water supply development for domestic use on the Russian River, Sonoma County, CA.

TOXIC AND HAZARDOUS CHEMICALS SOURCES

Once domestic supplies have been located, knowledge of locations of potential hazardous and/or toxic chemcial inputs must be developed, since an early warning site logically must be located between the potential source and the supply.

Chemical use in the Russian River basin may be divided into three broad categories: household, industrial, and agricultural. The household uses were assumed to be concentrated in urban areas and were not feasible to investigate. Data from a previous 205(j) project "Development of a Toxic and Hazardous Substance Control Program for the Russian River" (NCRWQCB, 1983) were used to identify major routes of transportation in the basin. Due to the topography of the basin, most of those routes are parallel to the Russian River or its tributaries.

Another major effort of that previous 205(j) project was the collection of data relating to the storage and use of hazardous and toxic chemicals in the basin (Warner, Brown, Goodwin, 1985). A computerized database of facilities that use and/or store hazardous and toxic chemicals was developed from questionnaires mailed to all businesses likely to use or store those chemicals. The data were grouped into 26 chemical classes and the amounts in storage and/or use were totaled. A computer program was designed and written for two purposes: 1) to query the database regarding the spatial distribution of chemicals by class in the basin, and 2) to query for information on users/storers of chemicals in the event a specific chemical is detected in the Russian River or a tributary. It should be noted that the data used in the database are from the 1983 and 1984 surveys.

Major agricultural chemical uses and areas were identified through review of the Regional Board files and interviews with staff of the county Agricultural Commissioners' offices (SCCAC, 1987; MCCAC, 1987).

Summary information on the potential sources of industrial and agricultural chemicals were combined on a basin map detailing the likely areas of concern and likely routes of input for hazardous and toxic chemicals into the Russian River (Figure 2). That information coupled with the locations of domestic water supply diversions (Figure 1) served as the basis for the initial siting of proposed early warning stations.

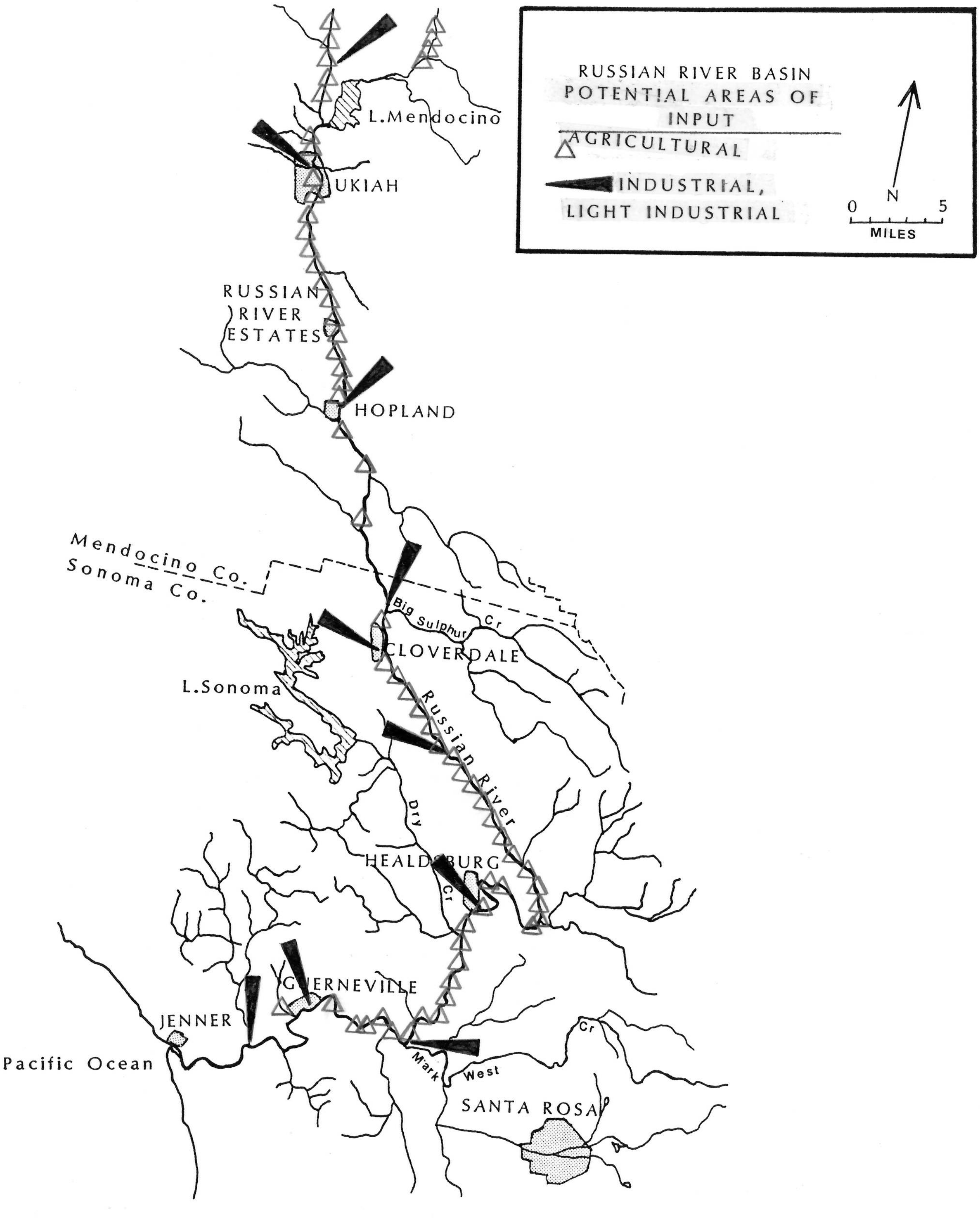

Figure 2. General areas of potential chemical input into the Russian River from agricultural areas and industrial sources. Note: Actual agricultural areas are not delineated, rather the potentially affected areas of the river are indicated.

RUSSIAN RIVER TRAVEL TIME ESTIMATES

With information on potential sources of chemicals and locations of domestic supplies, the final ingredient in locating potential early warning sites is some estimate of travel times in the river from point to point and at different river flow rates.

Travel times for the Russian River were calculated for the Russian River using three methods: 1) empirical data obtained during the formalin spill of March, 1982, 2) flood crest data from the Sonoma County Water Agency (SCWA), and 3) water speed data from the U.S. Geological Survey (USGS) routine flow rate measurements.

The formalin spill data consist of measured concentrations at various stations and times. Those data are from two pulses of formalin traveling downstream during the spill event. The formalin data are comparable to a dye tracer study with two separate injections near the Ukiah area, and were treated in much the same way as one would treat dye tracer data.

The flood crest travel time estimates represent a wave or flood crest. The U.S. Army Corps of Engineers (USACOE) subjected flood crest hydrographs from gauging stations in the Russian River to computer analysis to estimate flood crest travel times. Those estimates were taken from the SCWA emergency plan (SCWA, 1987).

Water speed measurements were obtained by USGS during routine river discharge rate measurements at selected gauging stations in the Russian River. Average speeds for cross-sections were used in a process to estimate travel times for the river.

More complete descriptions and examples of the three methods for travel time estimates are given in the appendix.

Comparison of Methods:

The formalin data very closely approximate what would be expected with a typical dye tracer travel time study. In such a study, an easily detectable dye would be introduced in a single release and the resulting pulse followed by sampling through time at numerous locations downstream. Discrete formalin concentration pulses were evident for the sampling locations at Hopland, Cloverdale, Healdsburg, and Wohler Bridge. Unfortunately for the purposes of this project, those peaks were well attenuated further downstream in the Guerneville area, and as such did not provide adequate data for estimating travel times to Guerneville. Travel time calculations for the two separate pulses from Hopland to Wohler Bridge were essentially the same: within 15 minutes at all sampling locations on the river. Taking the formalin data to be essentially the same as an empirical measurement, it may be used to validate other methods.

The use of water speed measurements to estimate travel time is a logical method if enough data are obtained to divide the river into many small segments for which an average and representative water speed is obtained. By calculating a *travel time for each segment, the cumulative travel time for a longer segment can be estimated by adding the smaller segments' travel times. Although water speed data for only four locations were available from the USGS measurements, the cumulative travel time estimates were very close to those for the formalin spill (Figure 3). The data for the lower discharge rates (approximately less than 1,000 cfs) were generally variable, thus those estimates are less reliable. Measurements by Regional Board staff in June of 1987 at the lower discharge rate of 300 cfs at Healdsburg resulted in a curve similar to those estimated from the USGS data, and provide confidence in the use of the USGS data for estimating river travel times.*

At a flow rate of 2,000 cfs the USACOE flood crest estimates were within 20 percent (3.3 hours) at Healdsburg, however appeared to overestimate the travel time from Healdsburg to Guerneville by 13 hours (46.3 vs. 33.3 hours) compared to the water speed-derived method (Figure 3). As mentioned earlier in this report, the USACOE data were primarily from flood flows and their estimates were for the prediction of flood crests from very high flows. It has been observed that the lower Mark West Creek system and the Laguna de Santa Rosa provide storage during high flows, increasing the travel time and decreasing the intensity of flood crests in the river downstream of Wohler Bridge. This relationship is suggested in the USACOE's model at low discharge rates, although it does not appear to be a real phenomenon below flood stages (Brick, 1987; SCWA, 1987; Markham, 1987).

On October 4, 1974, a sudden 3,000 cfs release was accidentally discharged from Coyote Dam at Lake Mendocino. The flow rate just downstream of the dam increased from 310 cfs to 3,660 cfs. That pulse attenuated in its course downstream, but was obvious at gauges from Coyote Dam to Guerneville. Although the flow rates were not as high nor constant as during the formalin spill, the plot of cumulative travel time vs. miles downstream from Hopland (Figure 3) is very similar to the line for formalin and virtually the same as the line for flood crest estimates from Hopland to Healdsburg. The flood crest line from Healdsburg to Guerneville increases in slope due to the inclusion of the storage effect of the Mark West Creek system, however the line for this accidental release remains relatively constant.

We believe all these data suggest three points:

1 - *the formalin spill data and water speed-derived estimates are logical estimates of travel times in the Russian River,*

2 - *by comparison to an accidental release from Coyote Dam, the flood crest estimates downstream of Healdsburg significantly overestimate travel times at less than flood stages, and*

3 - *by comparison to the formalin spill data, a wave of increasing flow rate ("flood crest") travels faster than actual particles of water.*

Based on those three points, we estimated travel times for the Russian River from the forks near Ukiah to Guerneville (Table 1, Figure 4). Those estimates were derived from the USGS water speed measurements with the exception of the 300 cfs estimates.

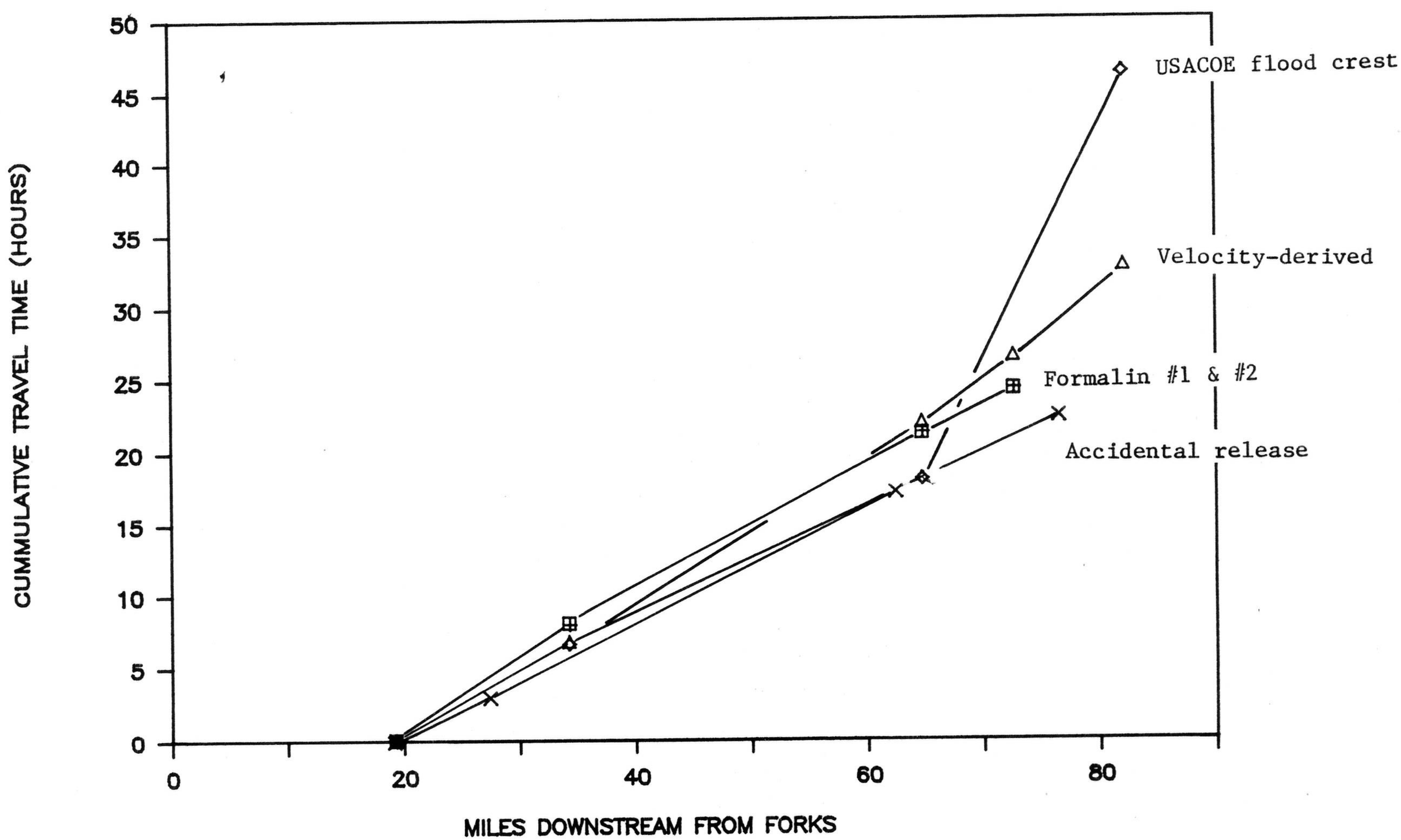

Figure 3. Comparison of Russian River cumulative travel time estimates at 2000 cfs from four methods of estimation: USACOE flood crest estimates, velocity-derived, formalin spill data, and accidental release from Coyote Dam.

Table 1. *Estimated cumulative travel times (hours) for the Russian River. Numbers in parentheses are 95 percent confidence levels for regression equations of water speed vs. river flow rate at each river location and flow rate. They may be applied to the estimates to provide lower and upper ranges for a travel time estimate.*

River flow	Cumulative Hours Of Travel From Forks (Calpella) To:				
Rate (cfs)	Hopland	Cloverdale	Healdsburg	Wohler	Guerneville
400	13.5* (46)	24.8 (68)	52.7 (90)	61.5	73.7 (112)
1,000	10.1 (35)	18.2 (49)	37.8 (63)	44.1	53.1 (83)
2,000	8.1 (29)	14.5 (38)	29.4 (49)	34.3	41.4 (67)
4,000	6.5 (24)	11.5 (30)	22.9 (38)	26.7	32.3 (54)
6,000	5.7 (22)	10.0 (26)	19.8 (33)	23.1	28.0 (48)
8,000	5.2 (21)	9.1 (23)	17.8 (30)	20.8	25.2 (44)
10,000	4.8 (20)	8.4 (21)	16.4 (28)	19.2	23.3 (42)
15,000	4.8 (20)	8.0 (18)	14.8 (25)	17.2	20.8 (38)
20,000	4.8 (20)	7.7 (17)	13.9 (23)	16.0	19.3 (35)

* Numbers in parentheses are 95 percent confidence levels for each regression equation.

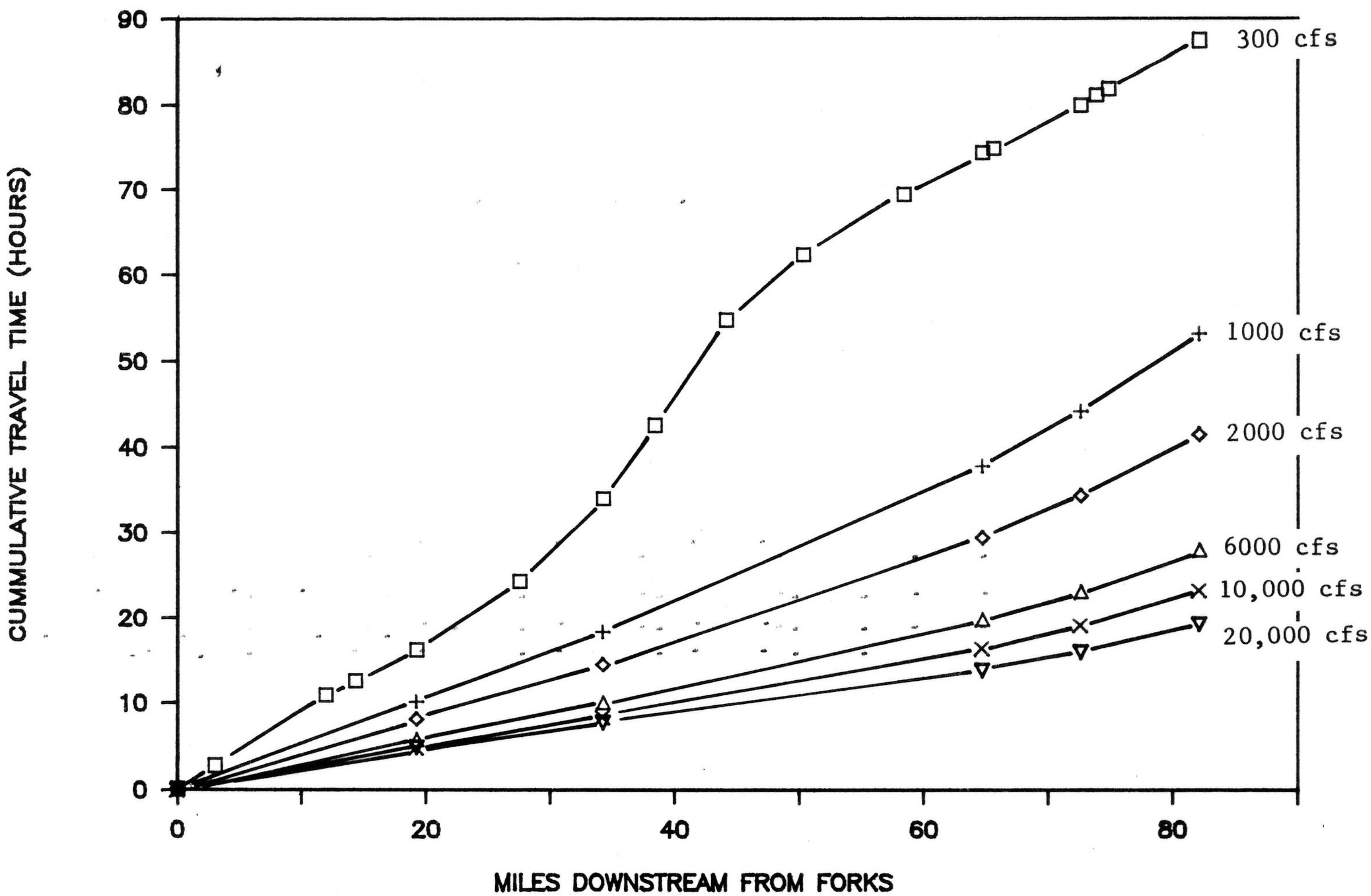

Figure 4. Cumulative travel time vs. miles downstream from the forks of the Russian River near Calpella, CA. Estimates derived from average speed vs. discharge rate near Hopland, Cloverdale, Healdsburg, and Guerneville, with the exception of the 300 cfs curve obtained from measured speeds in June of 1987 at numerous locations.

No current verification exists regarding the reliability of the travel time estimates. The estimates are based on sound logic and accurate data, but the database is small. The comparison to the formalin data reinforces the logic of the method and suggests a five percent (5%) maximum overestimation of travel time from the river forks near Calpella to Guerneville at 2,000 cfs.

The calculated 95 percent confidence intervals for the regression equations also provide information on the variability of the estimates (Table 1). One could calculate a conservative range of expected travel times from Hopland to Guerneville at 8,000 cfs as follows:

Travel time from Hopland to Cloverdale =
time from forks to Cloverdale - time from forks to Healdsburg =
9.1-5.2 = 3.9 hrs
range = 3.9 ± confidence interval for Cloverdale at 8,000 cfs
= 3.9 ± .23(3.9) = 3.9 ± 0.9
= 3.0-4.8 hrs

Travel time from Cloverdale to Healdsburg =
time from forks to Healdsburg - time from forks to Cloverdale =
17.8-9.1 = 8.7 hrs
range = 8.7 ± confidence interval for Healdsburg at 8,000 cfs
= 8.7 ± .30(8.7) = 8.7 ± 2.6
= 6.1-11.3 hrs

Travel time from Healdsburg to Guerneville =
time from forks to Guerneville - time from forks to Healdsburg =
25.2-17.8 = 7.4 hrs
range = 7.4 ± confidence interval for Guerneville at 8,000 cfs
= 7.4 ± .44(7.4) = 7.4 ± 3.3
= 4.1-10.7 hrs

Travel time from Hopland to Guerneville at 8,000 cfs =
(sum of lower ranges) to (sum of upper ranges) =
(3.0+6.1+4.1) - (4.8+11.3+10.7) =
13.2 - 26.8 hours =
20 ± 6.8 hours=
20 hours ± 34%

Although the task of travel time estimations is completed, we hope to verify the travel time estimates in the future. An addendum to this report will be produced to detail any future findings.

DISCUSSION AND RECOMMENDATIONS

In this instance, the objective of early warning is to provide water users with positive warning and sufficient notification time of harmful substances which have spilled into the river and thus their water supplies. Several criteria are attached to the "ideal" early warning site location, given the successful development of an early warning detection apparatus:

1 - *site located downstream of all potential and actual chemical inputs to the water supply (truly positive warning)*
2 - *site located far enough upstream of the water supply to provide adequate advance notification for a decision-making process (early warning)*
3 - *site located in close proximity to the river*
4 - *site easily accessible and secure in all weather conditions*
5 - *power and telecommunications available at the site location*

In theory, a network of many early warning stations may be developed for any river system to satisfy the primary objectives of providing warning of all deleterious chemicals in the water supply (truly positive warning), and providing sufficient time to shut down the affected supply and switch to another (early warning). In a practical sense, it is difficult to satisfy both objectives at the same time, since a chemical input may occur very close to the supply, closer than was originally thought when the network was designed. Such is the case in the Russian River. Some of the sites would be useful for providing the truly positive warning and not located far enough upstream to provide sufficient advance notification. Other sites would provide sufficient advance notification, however be located upstream of potential discharges or spills of chemicals into the water supply.

For those reasons, potential sites for an early warning system for the Russian River are proposed in three levels: 1) truly positive warning, 2) adequate early warning, and 3) some compromise between positive warning and early warning.

In the event an early warning system is put into operation on the Russian River, the agencies making that decision necessarily must strike a compromise and select sites based on budgetary and practical considerations.

Obviously, the only way to provide truly positive warning is to install an early warning device at every water supply intake. The Ohio River Valley Sanitation Commission instituted an early warning system with a primary site location criterion being a domestic water supply (OHRVSC 1981). Although the Commission used detection methods quite different from those being tested through this project, they realized the high priority of truly positive warning for domestic water users. Due to obvious budgetary constraints, the Commission did not operate a site at every water intake, rather provided warning to supplies downstream of the site using a river travel time model and interagency spill notification process.

Looking at early warning (advance notice), we plotted locations of sites at 8, 12, and 24 hours upstream of major supplies/zones at river discharge rates of 1,000, 6,000, 10,000, and 20,000 cfs (Figure 5, Table 2). Some sites are upstream of numerous supplies. Consequently, a site providing 24-hours notice for Guerneville at 1,000 cfs is very close to providing 12-hours notice for Healdsburg at 1,000 cfs and 8-hours notice for Wohler at 10,000 cfs (Table 2).

In the final analysis, we propose potential locations for early warning sites that:

1 - provide early warning (at least 8 hours), <u>and/or</u>

2 - are located between major potential hazardous or toxic chemical sources and water supplies.

Such a proposal resulted in a large number of sites without consideration for access and/or availability of power and telecommunications (Figure 6). Those are details that will be worked out by the involved agencies in the event an early warning network is instituted, i.e. sites likely would be moved to provide better access and necessary electrical and telecommunication facilities. We feel that adequate information is provided in this report to allow an agency (or agencies) to make decisions regarding the locations of early warning sites in the Russian River. The information on early warning notification times (miles upstream of public supplies) at various river flow rates are detailed in Table 3. All data relevant to our calculations are included in the Appendices with explanations of the calculations and logic; raw data and field notes are in the Regional Board's files and are a matter of public record.

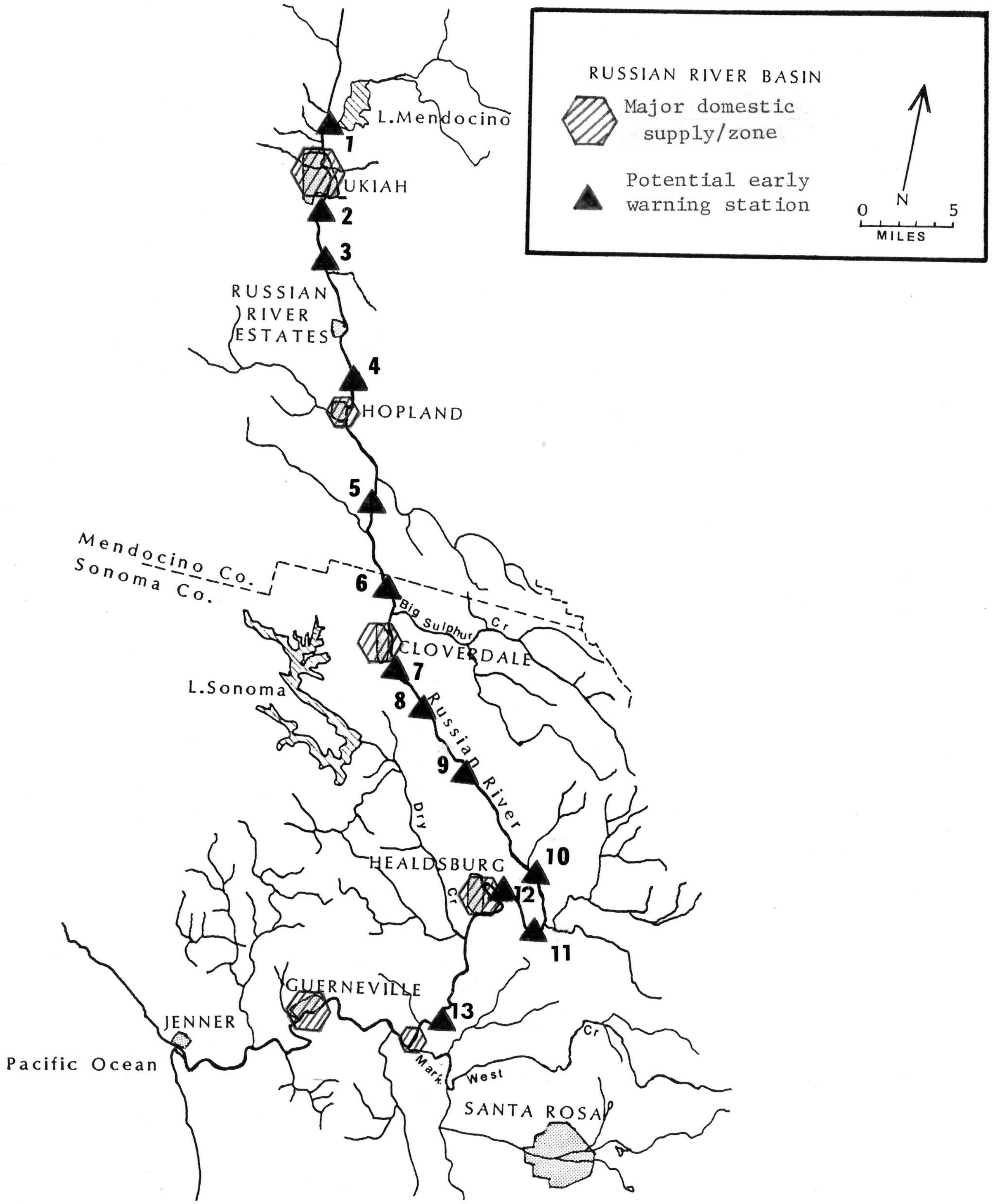

Figure 5. Locations of early warning sites based on advance notice of 8, 12, and 24 hours at 1,000, 6,000, 10,000 and 20,000 cfs discharge rates in the Russian River, CA.

Table 2. *Notification times for major Russian River diversion zones at various flow rates (measured at Healdsburg) for 13 proposed early warning sites in Figure 10. (All early warning stations for Ukiah and Hopland are upstream of Coyote Dam.)*

Early Warning Site	*Major Domestic Water Supply Diversion Zone:* Cloverdale	Healdsburg	Wohler	Guerneville
1	12 hrs @ 6,000 cfs			
2	8 hrs @ 10,000 cfs	12 hrs @ 20,000 cfs		
3	12 hrs @ 1,000 cfs 8 hrs @ 6,000 cfs			24 hrs @ 6,000 cfs
4	8 hrs @ 1,000 cfs	12 hrs @ 10,000 cfs	12 hrs @ 20,000 cfs	
5		24 hrs @ 1,000 cfs 12 hrs @ 6,000 cfs 8 hrs @ 20,000 cfs		
6				12 hrs @ 20,000 cfs
7		8 hrs @ 10,000 cfs	24 hrs @ 1,000 cfs 12 hrs @ 6,000 cfs 8 hrs @ 10,000 cfs	
8		8 hrs @ 6,000 cfs		12 hrs @ 10,000 cfs
9		12 hrs @ 1,000 cfs	8 hrs @ 10,000 cfs	24 hrs @ 1,000 cfs
10		8 hrs @ 1,000 cfs	8 hrs @ 6,000 cfs	12 hrs @ 6,000 cfs 8 hrs @ 20,000 cfs

Table 2. Continued

Early Warning Site	Major Domestic Water Supply Diversion Zone: Cloverdale	Healdsburg	Wohler	Guerneville
11			12 hrs @ 1,000 cfs	
12			8 hrs @ 1,000 cfs	12 hrs @ 1,000 cfs 8 hrs @ 6,000 cfs 8 hrs @ 10,000 cfs
13				8 hrs @ 1,000 cfs

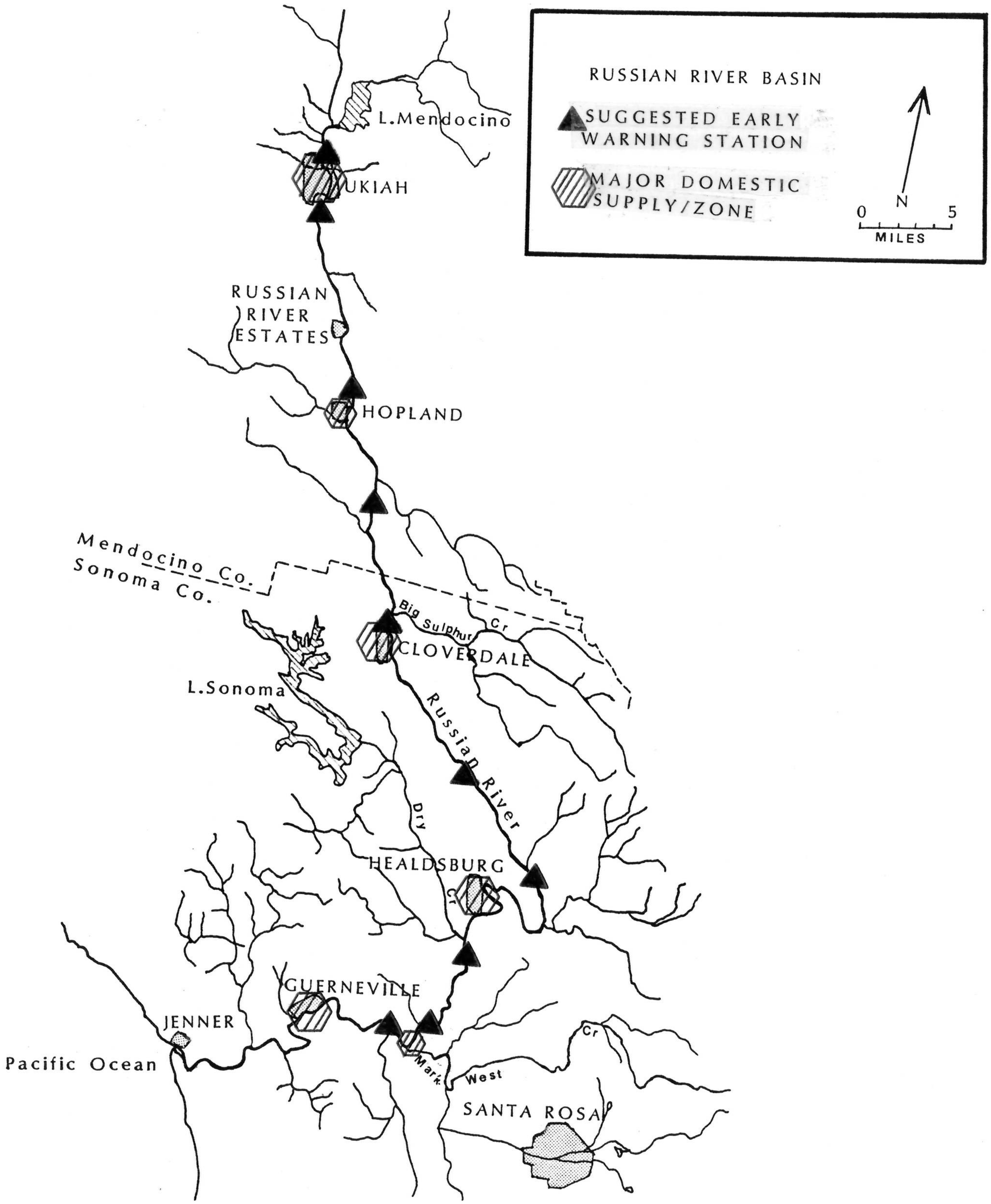

Figure 6. Suggested potential early warning sites for detection and advance warning of toxic substances in the Russian River, CA. Refer to Figure 5 and Table 2 for notice times at various river discharges.

Table 3. *Mileages upstream of major domestic water supply zones to provide eight-, twelve-, and 24-hours' notice at 1,000, 2,000, 6,000, 10,000 and 20,000 cfs river flow rates as measured in the Russian River at Healdsburg.*

River flow Rate (cfs)	Notice (hrs)	Miles Upstream Of: Hopland	Cloverdale	Healdsburg	Wohler	Guerneville
1,000	8	15	13	13	11	10
	12	**	20	19	17	14
	24	**	**	40	36	31
2,000	8	18	16	18	15	13
	12	**	25	25	23	19
	24	**	**	52	49	45
6,000	8	**	28	27	25	18
	12	**	**	38	37	31
	24	**	**	**	**	72
10,000	8	**	30	31	29	23
	12	**	**	49	48	39
	24	**	**	**	**	**
20,000	8	**	31	40	38	33
	12	**	**	57	57	52
	24	**	**	**	**	**

** Location is at or beyond Lake Mendocino.

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