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EFFECTS OF DEICING SALTS ON
THE CHLORIDE LEVELS IN WATER
AND SOIL ADJACENT TO ROADWAYS

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EFFECTS OF DEICING SALTS ON THE CHLORIDE LEVELS IN WATER AND SOIL ADJACENT TO ROADWAYS

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Research Project 71 G-180
Research Report No. R-1022

Lansing, October 1976

ABSTRACT

A Michigan Department of State Highways and Transportation study of the effect of deicing salts on roadside groundwater wells and surface soils has been reactivated. Twenty-nine groundwater observation wells were placed at test locations along three Michigan freeways to monitor groundwater chloride levels adjacent to roadways receiving winter deicing salt applications. Forty-seven surface sampling sites were established to measure sodium and chloride levels in roadside meltwater and shoulder soils. Approximately 319 miles of roadway are included in the study. A general sampling location plan and observation well locations indicate the field data collection points. Figures present preliminary chloride data from test results of samples obtained in early 1976. Sampling is continuing.

INTRODUCTION

Initial Study

In 1971, the Michigan Department of State Highways and Transportation began a study of the effects of roadway deicing salts on the chloride levels in roadside soils and groundwater. Sampling locations were established along a major north-south state trunkline system to monitor deicing salt infiltration in areas experiencing winter conditions ranging from heavy snow accumulations in the northern Lower Peninsula, to sleet and freezing rain in the southern region of the State.

The pilot phase of the study involving selection of suitable sampling locations, placement of test wells, and development of sample testing procedures was accomplished during the 1971-72 period. From the initial test findings a format for routine sampling was established. Sampling proceeded into 1973 at which time the study was temporarily suspended due to loss of qualified personnel.

Present Study

In 1975, increasing concern over the harmful effects of deicing salts led to reactivation of the study. In addition to the monitoring of chloride levels at selected field locations the study includes an active literature search for possible alternatives to the use of chloride deicers, and for recommended procedures to be followed to minimize the harmful effects of chlorides.

An Addenda section includes comments on: chemical alternatives to chloride deicers; corrosion inhibitors; heated pavements; and some summary remarks on these topics.

Groundwater Observation Wells

Before re-establishing the original field sampling sites, the performance of each location was evaluated. The existing well screens in most of the wells were found to be in poor condition requiring replacement. Several of the original wells, including an array on I 75 near Holly, were discontinued due to poor water recovery. An alternate test site, established to replace the Holly wells, is situated on the US 10 relocation north of Clare. This location was selected to study the progressive effects of deicing chlorides along a previously unsalted roadway. In all, 29 observation wells were placed at the four test locations. Depths to groundwater at the various locations range from approximately 28 ft at the I 75 (Grayling) site to less than 1 ft at the US 10 (Clare) site. Well points were set approximately 5 ft below water table. The test well locations are shown in Figures 1 through 5.

Meltwater and Soil Sampling Sites

Results of the prior 1972-73 samplings indicated a complex salt infiltration process at all locations. To recheck the initial findings and investigate the possible build-up of sodium and chloride in roadside soils, the sampling and testing of shoulder soil was repeated in 1976. Sampling and testing of meltwater was also resumed to provide supplemental information. Soil samplings are continuing in summer and fall of 1976 to establish the present base levels of sodium and chloride. The 47 meltwater and soil sampling locations established along the four roadway test segments are located as follows:

State Trunkline	No. of Sites
I 75 Roscommon to Flint	14
US 10 west from US 27	5
US 27 Lansing to Grayling	14
I 69 Lansing to Kinderhook	14

Supplemental Test Locations

Monitoring of groundwater has also been requested at a new deicing salt storage facility in the Reed City vicinity. Accumulated groundwater chloride data are required to evaluate the effectiveness of chloride containment at the storage site. The study of deicing salt levels in ponded water adjacent to roadways has been recommended. A tentative test location has been selected along I 275 near Carleton.

Testing Procedures

The initial testing of samples during the pilot phase of the study involved the use of several procedures including field and laboratory chemical titrations and electrical measurements. A review of the various methods suggested that laboratory testing of the large number of samples resulting from biweekly samplings would provide the most suitable processing format. Testing of the samples is conducted at the Department's Research Laboratory facility in Lansing. Water and soil samples are tested for chlorides by standard chemical titration procedures. Sodium levels are measured by specific-ion electrode determinations.

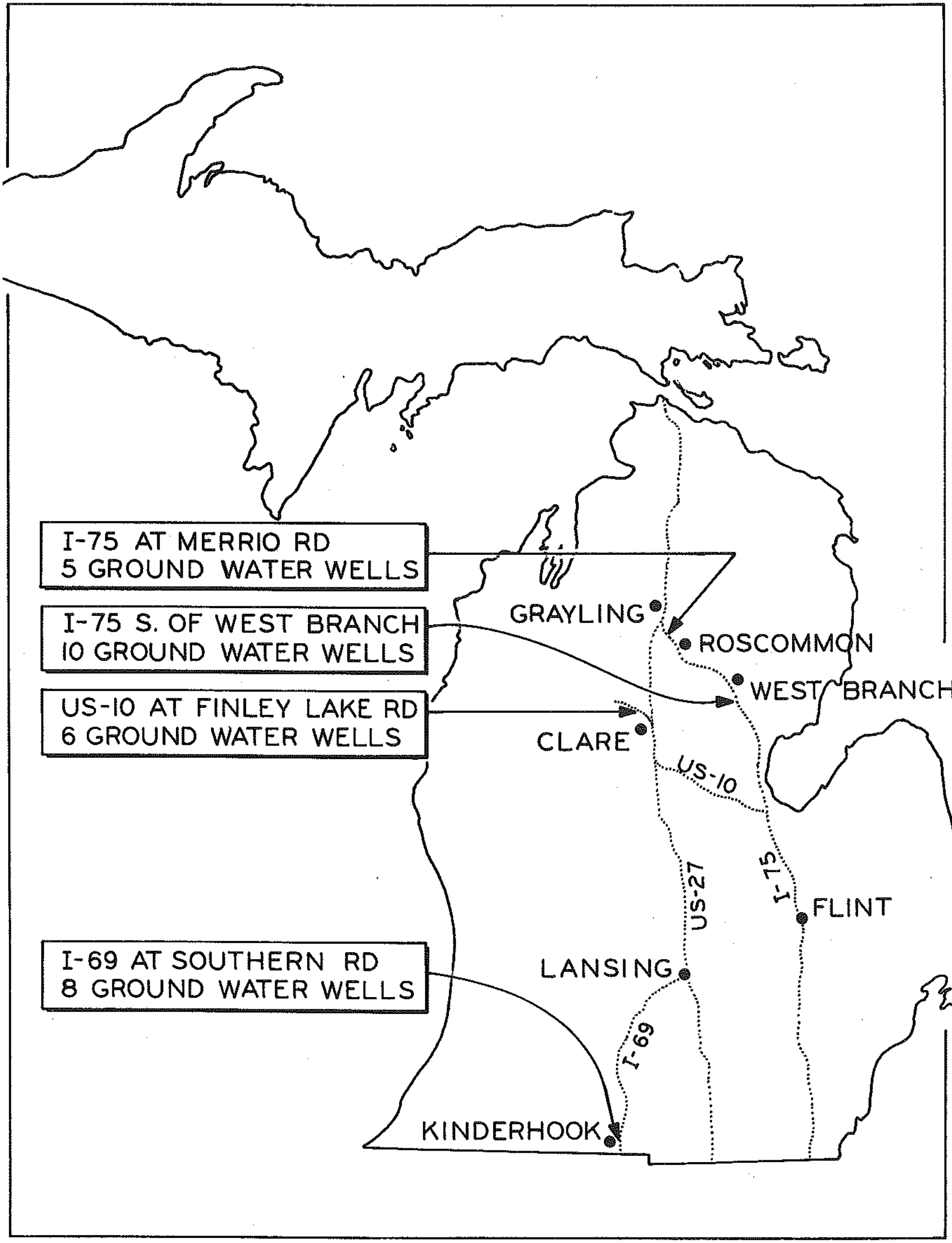


Figure 1. All groundwater well sampling locations.

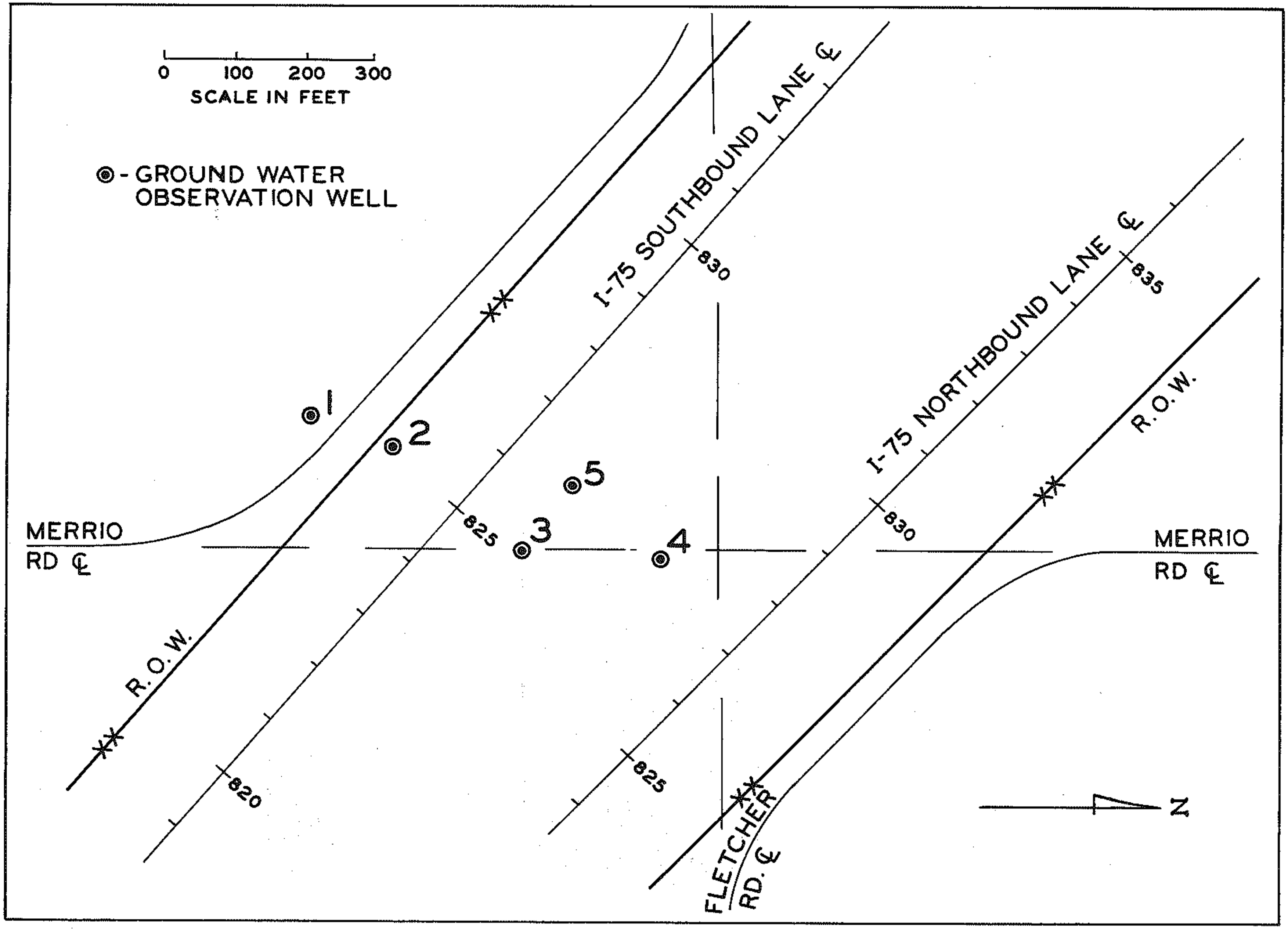


Figure 2. I 75 well locations: I 75 south of Grayling (Sections 20, 21, 28, 29, T25N-R3W, Beaver Creek Twp, Crawford Co.).

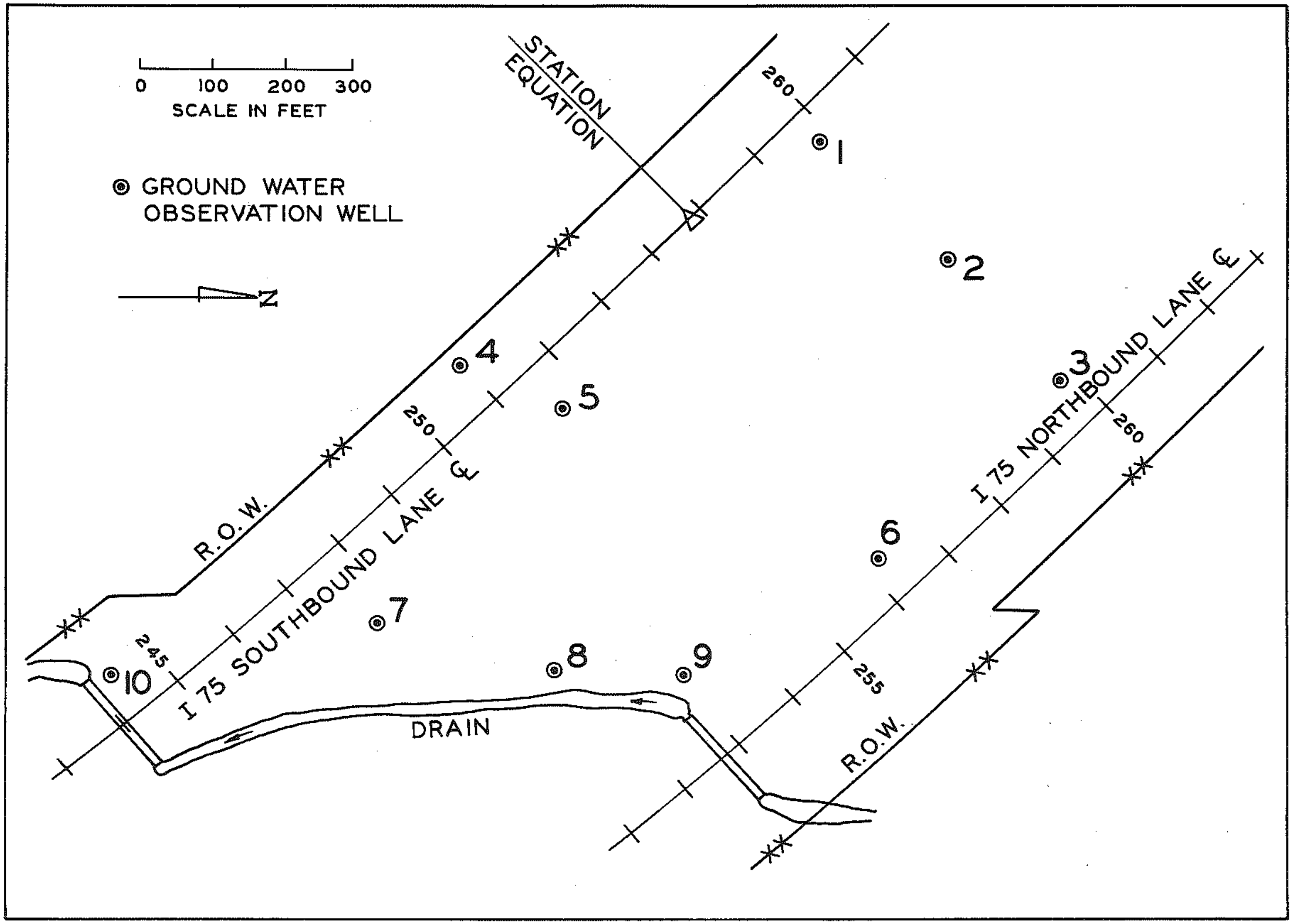


Figure 3. I 75 well locations: I 75 south of West Branch (Section 16, T21N-R2E, Horton Twp, Ogemaw Co.).

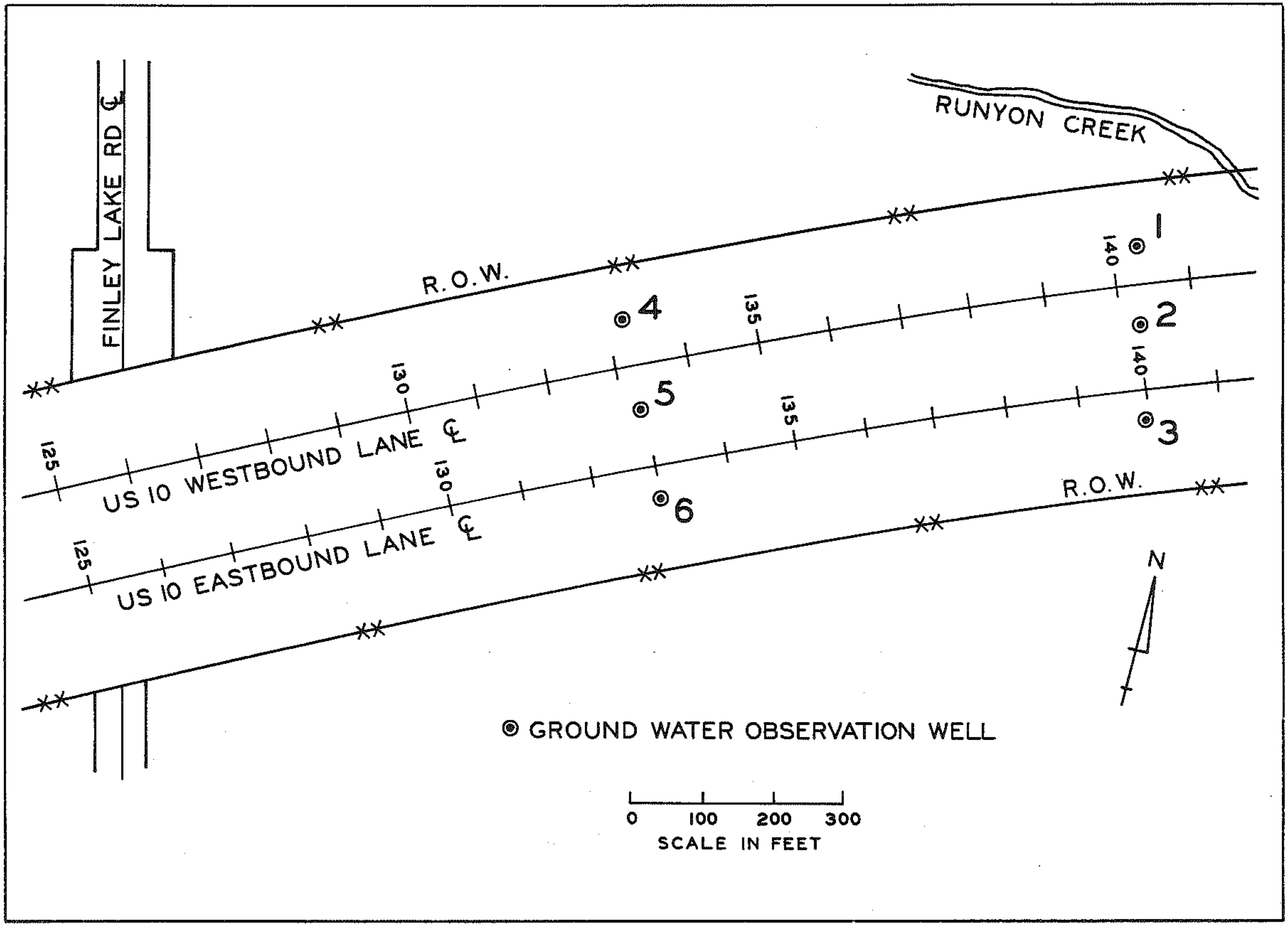


Figure 4. US 10 well locations: US 10, Finley Lake Rd area (Section 14, T17N-R5W, Surrey Twp, Clare Co.).

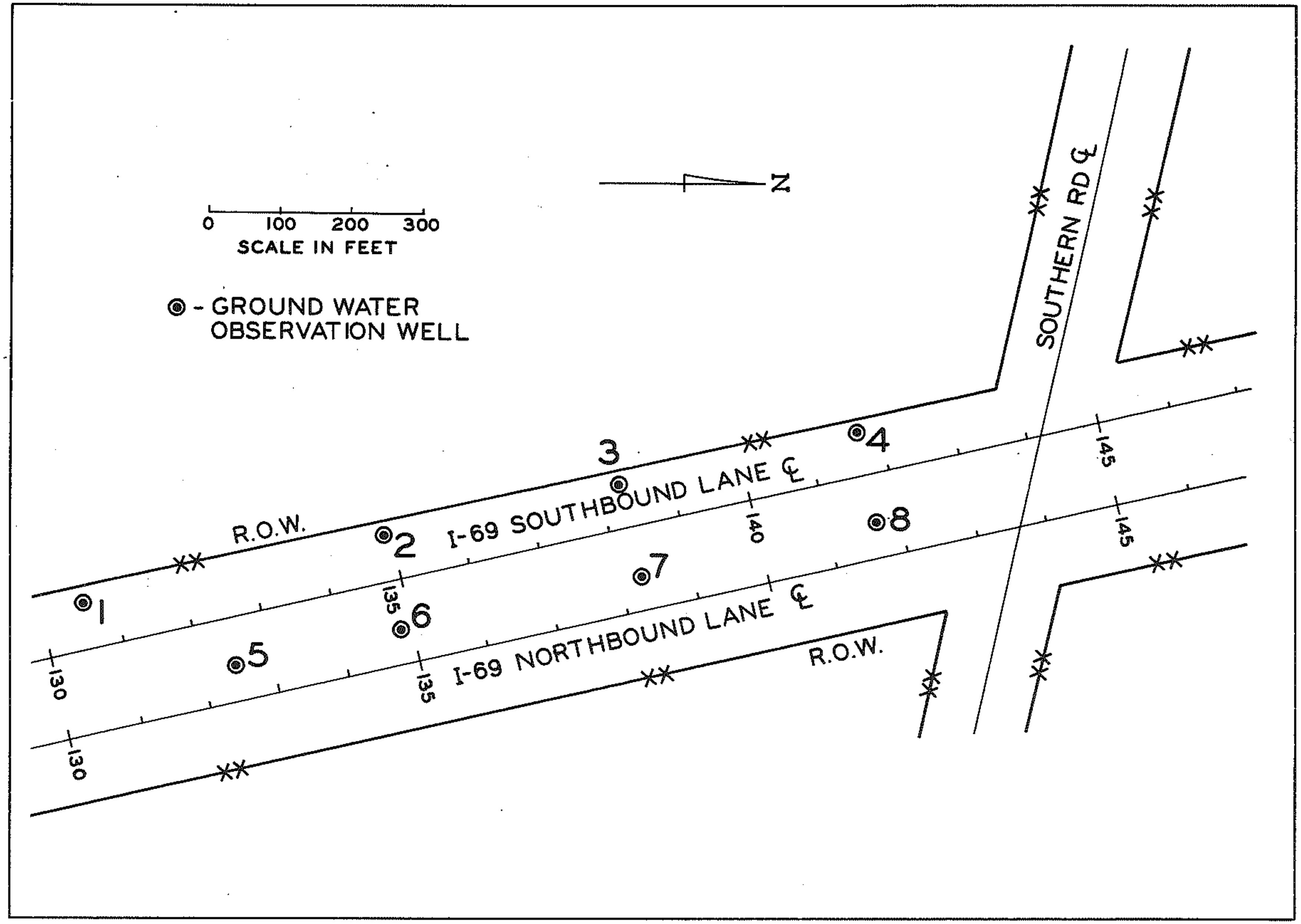
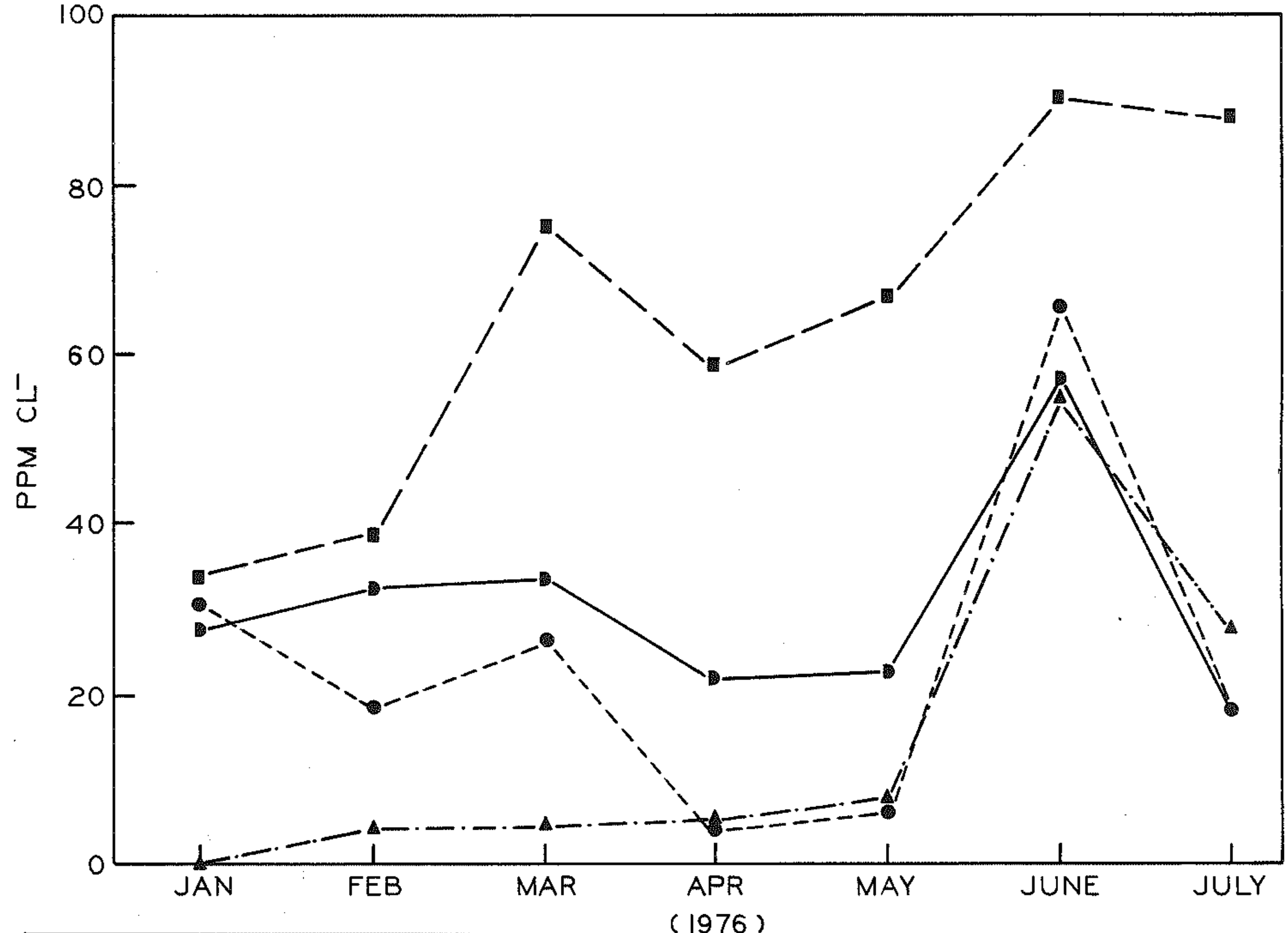


Figure 5. I 69 well locations: I 69, Southern Rd area (Sections 10 and 15, T8S-R6W, Kinderhook Twp, Branch Co.).



WELL SITES	NO. OF WELLS
● I-75 GRAYLING	5
▲ US-10 CLARE	6
◗ I-75 WESTBRANCH	10
■ I-69 KINDERHOOK	8

Figure 6. Chlorides in samples from groundwater wells.

PRELIMINARY FINDINGS

Groundwater Chlorides

The pattern of variation in groundwater chlorides recorded by the 1972-73 samples was repeated in the 1976 data. Due to the complexities of the chloride infiltration processes such fluctuations appear to be typical of conditions adjacent to roadways receiving salt deicing treatment. Similar findings were reported in the New England region (1).

An average monthly chloride level was computed for each test location, incorporating data from all wells. Figure 6 summarizes the results of 345 water samples obtained during the 1976 winter-spring period. Chloride levels at the I 75 and I 69 test locations are generally higher than those at the US 10 test location. The I 75 and I 69 roadways have been salted for a number of winter periods whereas the newly opened US 10 roadway has received few applications. A seasonal surge of chlorides is indicated by the data from samples obtained through the month of July.

Sample results indicated that the groundwater chloride levels at the four test locations appear to be considerably below the U. S. Public Health Service recommended maximum of 250 ppm for potable water (2).

Roadside Meltwater Chlorides

The median and roadside ditch meltwater samples obtained in 1976 recorded wide fluctuations similar to the earlier samplings. Average monthly chloride levels computed from the test results of 320 samples collected from the 47 roadside locations are summarized in Figure 7. Average chloride levels along the roadways having had more deicing applications were found to be much higher than those along the newly opened route.

Samples obtained in April indicated that chloride migration occurred in the spring thaw period. Efforts to obtain samples later than April were abandoned due to dry-up of many sources.

The average roadside meltwater chloride levels were found to be considerably below the 1,500 ppm maximum in water safe for drinking by livestock and wildlife, as stated by the California State Water Quality Board (3).

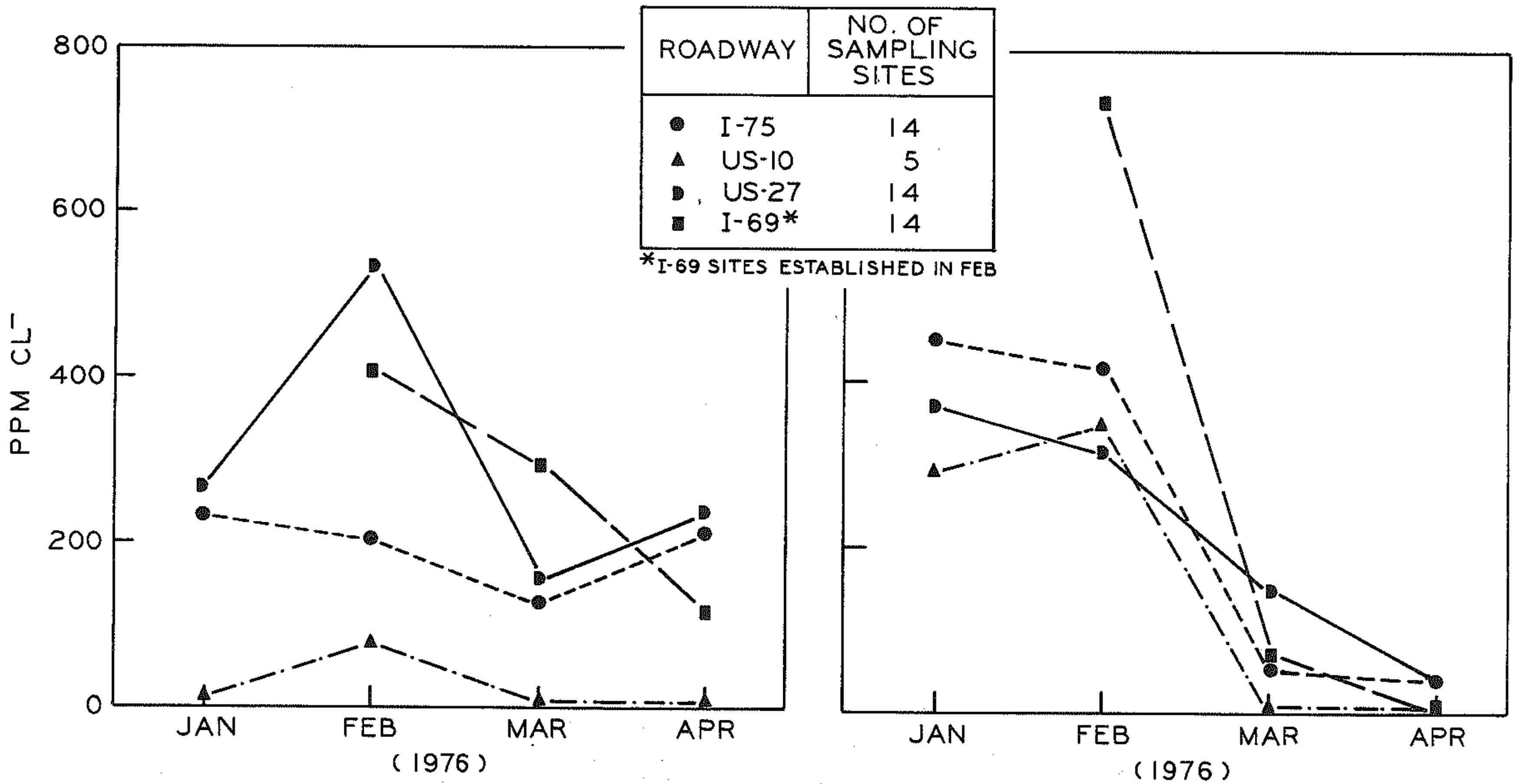


Figure 7. Chlorides in ditch and median meltwater samples.

Figure 8. Chlorides in shoulder soil samples.

Shoulder Soil Chlorides

Chloride levels in shoulder soil samples obtained a few feet off the edge of the outside paved shoulders were found to exhibit a considerable variation, with higher values recorded along the more heavily traveled roadway segments. Figure 8 summarizes the average monthly chloride levels computed from the results of 320 samples obtained from the 47 sampling sites during the 1976 period. Levels were found to decline rapidly along all test roadways with the arrival of the spring thaw. Similar springtime chloride decreases have been reported in the New England region (4).

Soil chlorides from the winter sampling at a number of individual sampling sites were found to exceed 1,000 ppm. However, chloride levels were found to have declined to levels below 200 ppm by late spring. Observation of roadside vegetation along the test roadways in July revealed an apparently normal grassy cover on the shoulder soil along all of the test roadways. An Iowa study of the effects of deicing salts on grasses states that roadside grasses tolerate chloride levels considerably above those observed along the test roadways during the growing season (5). The study also states that chlorides below 600 ppm sodium chloride (347 ppm chlorides) actually stimulated growth in all grasses tested.

Types of vegetation other than cover grasses are generally situated beyond the splash zones along the test roadways. A study of salt damage to trees in New Hampshire revealed that trees located at least 30 ft away from salted roads were generally not harmed by deicing salts (6).

Sodium levels in the roadside soils are being monitored for possible build-up. Since previous sampling did not include such data, comparisons can not yet be made.

DISCUSSION

The preliminary results of field sampling indicate that chloride levels associated with deicing salts along Michigan roadways are similar to those studied in other snowbelt states. The general association between the increased chloride levels in the soils and meltwater adjacent to roadways in the winter is evident. The same increase is noted in well water, though it occurs later in the year.

Test results indicate that chloride concentrations at specific locations along the test roadways deviate considerably from the average levels. We suspect that causes for the deviations are complex, though an interrelationship between salt usage and salt concentration at road sites must exist.

ADDENDA

A. Chemical Alternatives to Chloride Deicers

In 1973 a summary of various deicing agents was compiled at the Department's Research Laboratory.

According to the literature reviewed in preparation of the summary more than 25 non-chloride chemical deicing agents have been evaluated in recent years (7, 8, 9). Only urea and liquid glycols were found to be in use to any extent. Two other agents, urea-calcium formate and tetra-potassium pyrophosphate (TKPP) were mentioned as possible alternatives to chlorides.

The 1973 summary included the following estimated costs of the most effective non-chloride chemical deicing agents as compared to the cost of sodium chloride, based upon the amounts needed to achieve an equivalent ice-melting effect.

Material	Estimated Cost Equivalent to One Unit of Sodium Chloride
Sodium Chloride	$1
Urea or Urea Mixture	$ 8 - $ 16
Liquid Glycols	$60 - $260
TKPP	$70 - $350

Chemical agents containing phosphates or nitrogen are potential sources of excessive nutrients which could cause undesirable biotic changes in aquatic environments reached by roadway run-off. Unfortunately, many of the non-chloride chemical deicers that have been investigated contain such nutrients. Most of the agents studied are chemically more complex than chlorides and are capable of alteration to potentially harmful by-products.

B. Corrosion Inhibitors

Results of a Departmental study on the effect of corrosion inhibitors for deicing chlorides indicated that due to toxicity, cost, and poor effectiveness the use of such agents was not recommended (10). The study also found that almost 50 percent of the observed corrosion on test vehicles occurred during the time of year when roads were not being treated with deicers.

C. Heated Pavements for Ice Control

The use of heated pavements for ice control was reviewed by a study group of the National Association of Corrosion Engineers (NACE) (11). The per-mile cost of constructing a four-lane interstate highway equipped with ice-prevention heaters was estimated at $8 million, many times the cost of a conventional highway. The cost of maintaining and operating heated pavement systems was also extremely high.

D. Summary Remarks

The NACE study (11) found that sodium chloride, although corrosive, offered the best combination of cost and deicing properties. Calcium chloride, another effective deicer, but more corrosive, was stated to cost over three times as much as sodium chloride. The study indicated that the use of chlorides for roadway deicing is necessary to continue the bare-pavement concept required for safe winter driving in the snowbelt regions.

The continued use of chloride deicers appears to be an economic necessity at the present time. However, many of the studies reviewed state that the adverse effects of chloride can be reduced through greater use of preventive measures including corrosion protection and a more conservative use of chlorides for the deicing of highways.

A comprehensive study prepared for the U. S. Environmental Protection Agency indicates an estimated total annual cost of $2.91 billion to the snowbelt states resulting from the use of road salt (12). Of that figure, $2.0 billion is assigned to effects on vehicles, indicating the acute need for better vehicle corrosion protection. The study concludes that while the damages to vehicles and structures can be reduced by protective measures, harmful effects of chlorides due to pollution of water supplies can only be lessened by reduced usage of chlorides.

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