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

Interim Progress Report

MICHIGAN DEPARTMENT OF TRANSPORTATION

MATERIALS and TECHNOLOGY DIVISION

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Effects of deicing salts on the chloride levels in water and soil adjacent to roadways : interim progress

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

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ABSTRACT

The Michigan Department of Transportation established a statewide investigation in 1971 to monitor the environmental effects of salt applied to roadways for winter maintenance ice control. Monitoring included 47 roadside locations for sampling soil and runoff water, four streams, and 30 ground water wells at four locations. Chloride levels in roadside pond water and subgrade water were also monitored. The investigation continued from 1971 to late 1984.

Roadside soils, surface waters, and ground water were found to have chloride levels within published limits of tolerance for plant and animal life. The chloride levels in the ground water were noted to reach a relatively stable state in which the annual precipitation water combined with the ground water to dissipate the winter maintenance deicing salt at acceptable chloride levels.

Results of the investigation indicated that no remedial action was necessary at any of the monitor sites. Recommendations included continued use of salt, with emphasis on reduced usage by improving the control of spreading rates and greater use of sand-salt mixtures.

A limited continuation of chloride monitoring at selected sites was recommended.

INTRODUCTION

In 1971, the Michigan Department of Transportation approved a research project titled "Effects of Deicing Salts on the Chloride Levels in Water and Soil Adjacent to Roadways." The project proposal listed the following objectives:

1) Develop a methodology for determining the rate of movement and dilution of deicing salt solutions in the surface and subsurface waters away from highways located on porous soil where near-surface, unconfined aquifer (open to surface infiltration) conditions exist.

2) Determine the concentration of chloride in surface runoff on a statewide basis.

3) Determine the rate of ground water movement and levels of contamination originating from normal highway salting.

4) Make recommendations for remedial treatment if significant contamination is occurring.

The pilot phase of the investigation involving selection of sampling locations, placement of ground water monitor wells, and development of sample test procedures was conducted during the 1971-73 period. The investigation was deactivated in 1973 due to loss of personnel. In 1975 the investigation was reactivated; review of the original well emplacements was conducted, and monitor wells were re-established where necessary. One of the original well arrays was replaced with an array on a recently opened trunkline to monitor the progressive effects of deicing chlorides in a new roadway environment. A total of 30 ground water observation wells were established at four test locations along major trunklines. In addition to the ground water monitoring, ditch water and soil were sampled from 47 locations along four trunklines.

In October of 1976, a progress report was issued (1). The report presented the results of the field monitoring conducted during the initial six-month period. The report also included a brief addendum on alternatives to deicing salt.

This report presents the results of field monitoring conducted during the 1976-84 period. During the course of the investigation streams and pond locations were added for chloride monitoring. This report also includes site descriptions of the ground water monitor locations, and records of deicing salt usage and precipitation in the areas covered by this investigation.

SAMPLING AND ANALYSIS

The sampling format for this investigation was structured to monitor the migration of roadway deicing salt outward and downward into the roadside environment. Long-term monitoring was scheduled to include biweekly to monthly samplings of soils, as well as water from ditches,

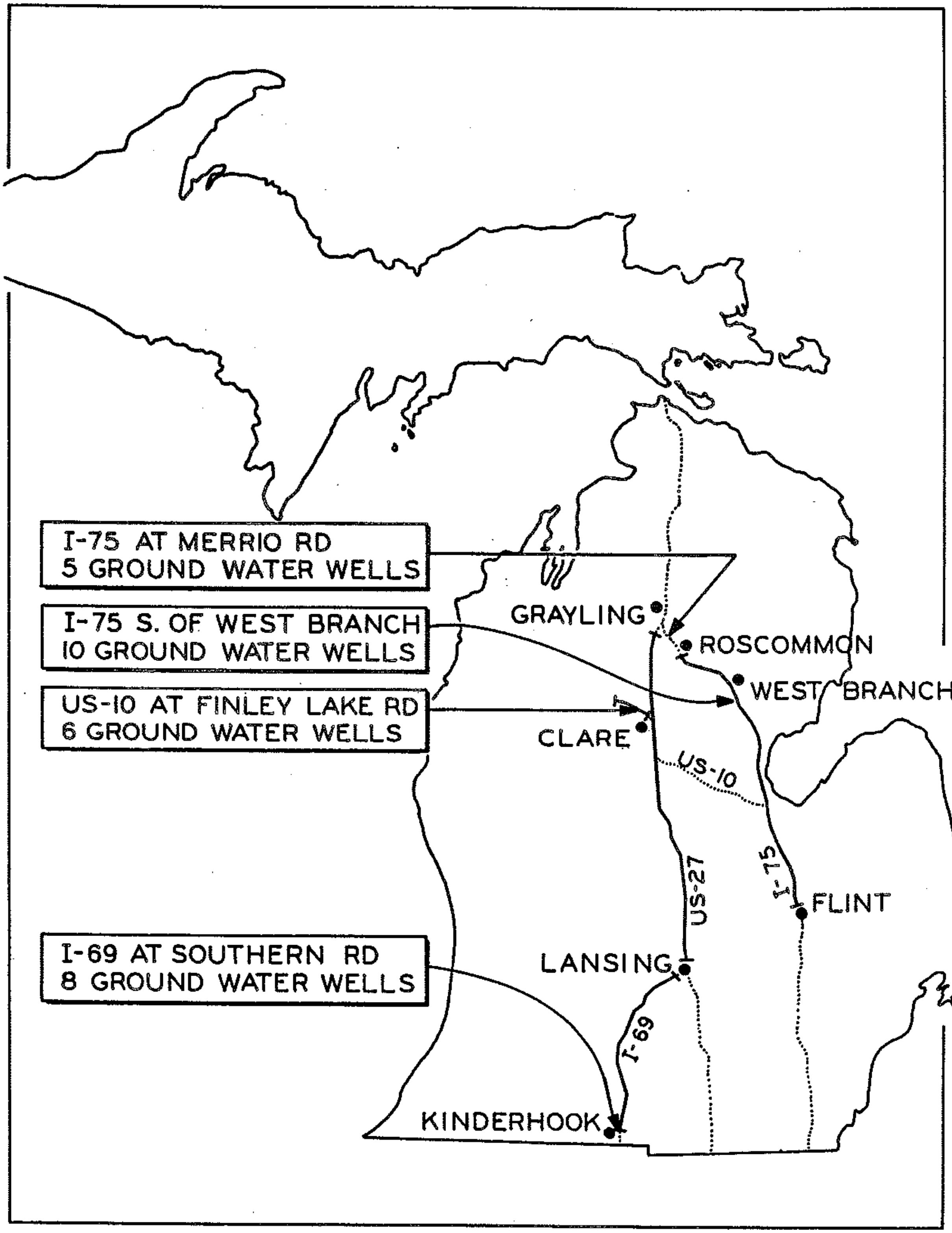


Figure 1. Locations of ground water wells and state trunkline segments monitored.

medians, ponds, streams, and ground water observation wells in the immediate roadside environment. Segments of north-south trending trunklines extending from the northern Lower Peninsula to the Michigan-Indiana state line were selected to include a range of winter precipitation types, from deep snow in the north to sleet and freezing rain in the south. Figure 1 indicates the trunkline segments and ground water monitor sites.

Ground water observation wells were established at the selected sites by truck-mounted auger. Four-foot, 1-1/4 in. diameter PVC well points with 0.01-in. slots were emplaced with the screen-tops 2 to 4 ft below the local water table.

Soil samples for this investigation were obtained by bucket auger or hand shovel. Surface water samples were obtained by dip-sampler. Water samples from the monitor wells were obtained by centrifugal pump or pitcher pump.

Water extracts for chloride analysis were prepared from the soil samples according to procedures outlined by M. L. Jackson (2). Chloride analyses of the soil extracts and water samples were conducted according to the Mohr silver nitrate titration procedure (3).

Field samples were obtained at biweekly to monthly intervals, resulting in a large accumulation of data from the 1976 through 1984 monitoring period. To present an overview of seasonal variations and long-term trends in chloride levels, monthly to quarterly average values were computed and plotted as bar graphs. Chlorides are expressed as ppm Cl^-.

GROUND WATER MONITOR SITE DESCRIPTIONS

I 75 Wells South of Grayling - A five-well array was established along a northeast-southwest trending valley extending toward Beaver Creek approximately one mile to the south. The area is included in the AuSable River drainage basin (4).

The wells were situated in sands and gravels mapped as interlobate outwash deposits of the Michigan and Saginaw lobes of Wisconsin glaciation (5). The local water table is approximately 25 ft below ground surface, with inferred migration to the southwest at a low hydraulic gradient of 0.002 ft/ft, and a field velocity of 3 in./day. The inferred direction and rate of movement was determined from water table measurements and soil type, according to data from "Ground Water," by C. F. Tolman (6). Adjacent land varies from woods to grassy fields. Figure 2 indicates the well locations.

I 75 Wells South of West Branch - An eleven-well array was established in a flatland area bounded to the south by LaPorte Creek which crosses the roadway at this location, and enters the East Branch of the Tittabawassee River approximately 2-1/2 miles to the south. The area is included in the Tittabawassee River drainage basin (4).

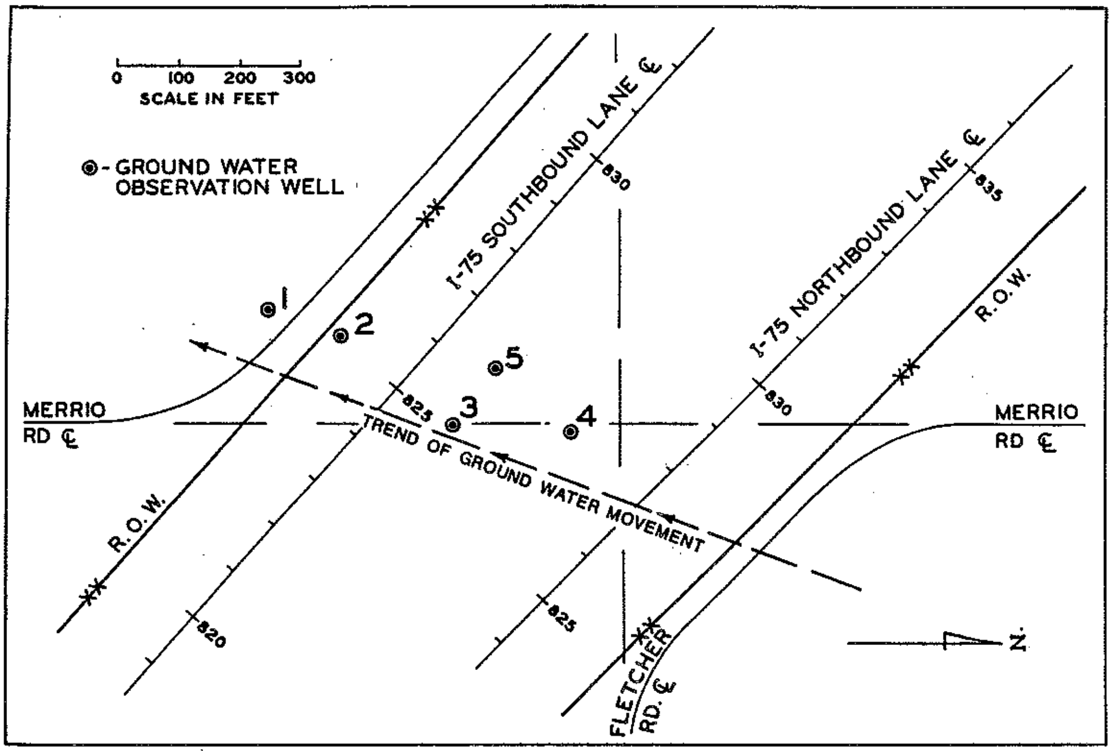


Figure 2. I 75 well locations: I 75 south of Grayling (Sections 20, 21, 28, 29, T25N-R3W, Beaver Creek Twp, Crawford Co.). Roadway opened to traffic in 1971.

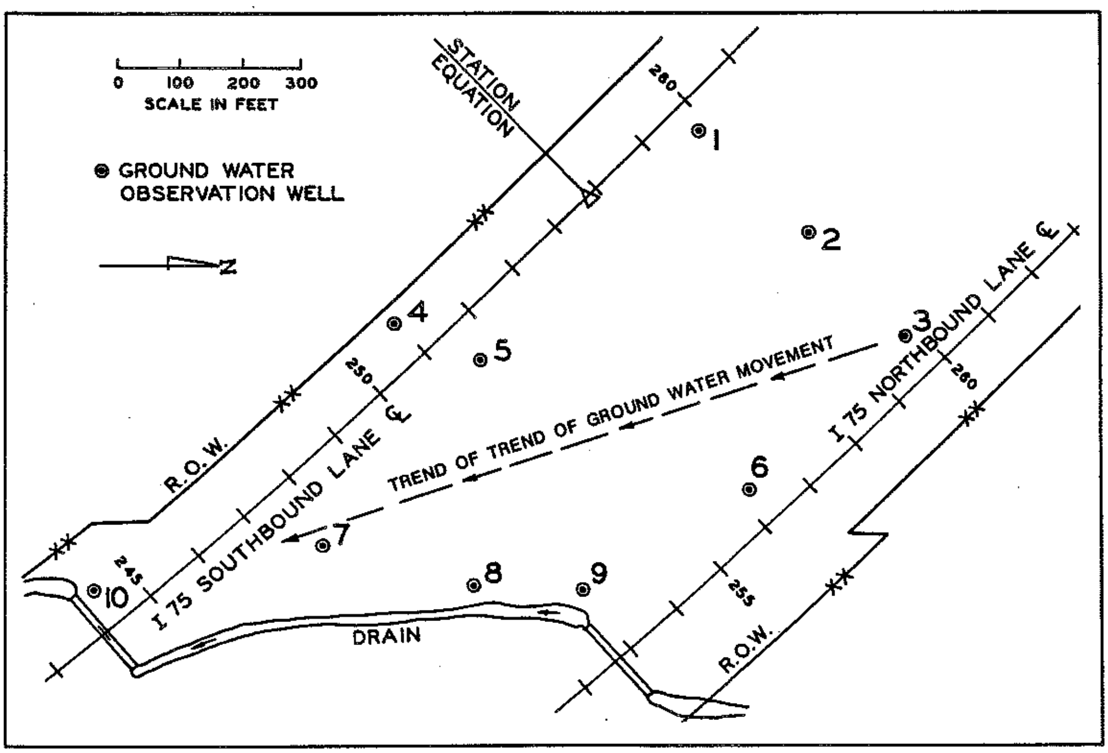


Figure 3. I 75 well locations: I 75 south of West Branch (Section 16, T21N-R2E, Horton Twp, Ogemaw Co.). Roadway opened to traffic in 1971.

The wells were situated in sandy soils mapped as moranic outwash deposits of the Saginaw lobe of Wisconsin glaciation (5). The local water table is approximately 3 ft below ground surface, with inferred migration to the southeast at a low hydraulic gradient of 0.005 ft/ft, and a field velocity of 7 in./day. Adjacent land is wooded and swampy. Figure 3 indicates the well locations.

US 10 Wells Northwest of Clare - A six-well array was established in an area of sandy hills drained by feeder creeks of the Tittabawassee River drainage basin (4).

The wells were situated in sandy soils mapped as ground moraine of the Saginaw lobe of Wisconsin glaciation (5). The local water table is approximately 1 ft below ground surface, with inferred migration easterly at a low hydraulic gradient of 0.007 ft/ft, and a field velocity of 8 in./day. Adjacent land consists of wooded hills and swampy lowlands. Figure 4 indicates the well locations.

I 69 Wells South of Kinderhook - An eight-well array was established on a flatland area mapped as an outwash plain of the Erie lobe of Wisconsin glaciation (5). The area drains into Silver Lake approximately one-half mile to the southwest. The locale is included in the St. Joseph River drainage basin.

The wells were situated in sandy soils, with water table approximately 4 ft below ground surface. Inferred ground water migration is westerly at a low hydraulic gradient of 0.004 ft/ft, and a field velocity of 3 in./day. Adjacent land is pasture and cultivated fields. Figure 5 indicates the well locations.

FINDINGS

Soils

Roadside Shoulder Gravel - Shoulder gravel samples were obtained from 47 sites along four trunklines at biweekly to monthly intervals during 1976 and 1977 to determine the seasonal chloride levels in surface soils immediately adjacent to the roadways.

Results of the samplings are shown in Figure 6. The results indicate that residual chloride from winter maintenance salt applications to the roadways is rapidly dissipated during the seasonal spring thaw periods.

Soils at Ground Water Monitor Wells - In 1976, reconnaissance samples of surface soils were obtained at the four ground water monitor sites. Resamplings in 1983 and 1984 were expanded to include soil to a depth of 3 ft to check for possible chloride build-up in the soil above the water table. Samples were obtained from the 0 to 1, 1 to 2, and 2 to 3-ft horizons at locations 15 ft from the roadways at selected wells. Table 1 gives the results of the samplings. The results show no evidence of long-term chloride build-up in the soils.

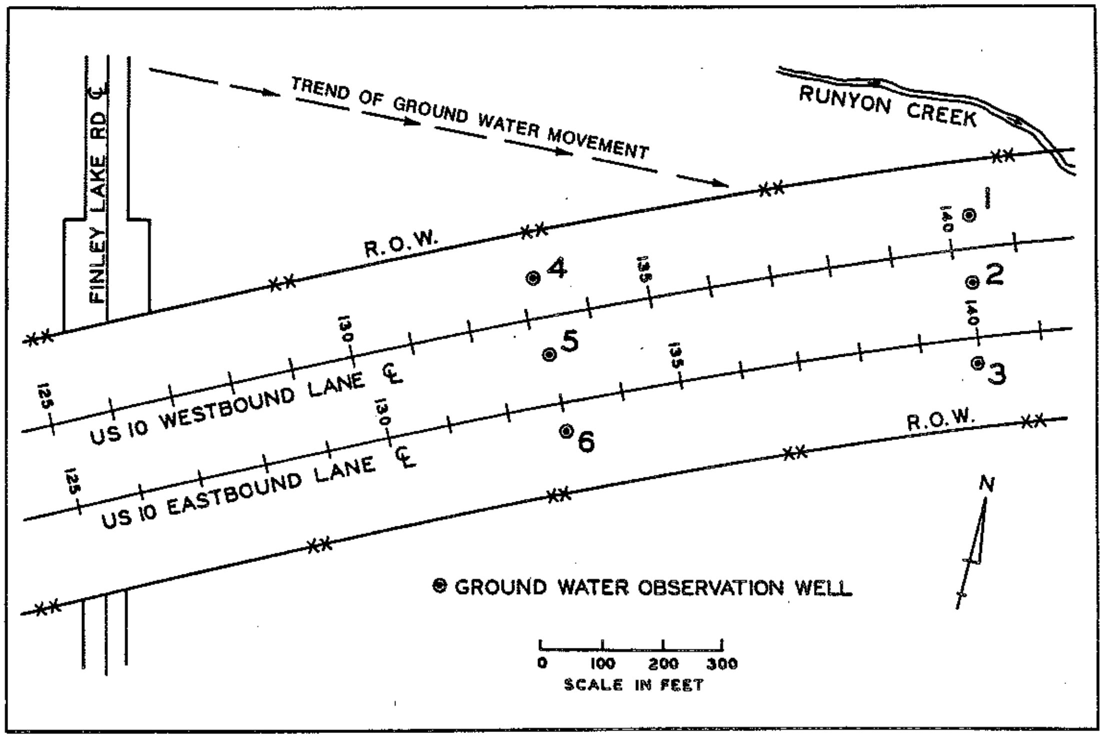


Figure 4. US 10 well locations: US 10, Finley Lake Rd Area (Section 14, T17N-R5W, Surrey Twp, Clare Co.). Roadway opened to traffic in 1975.

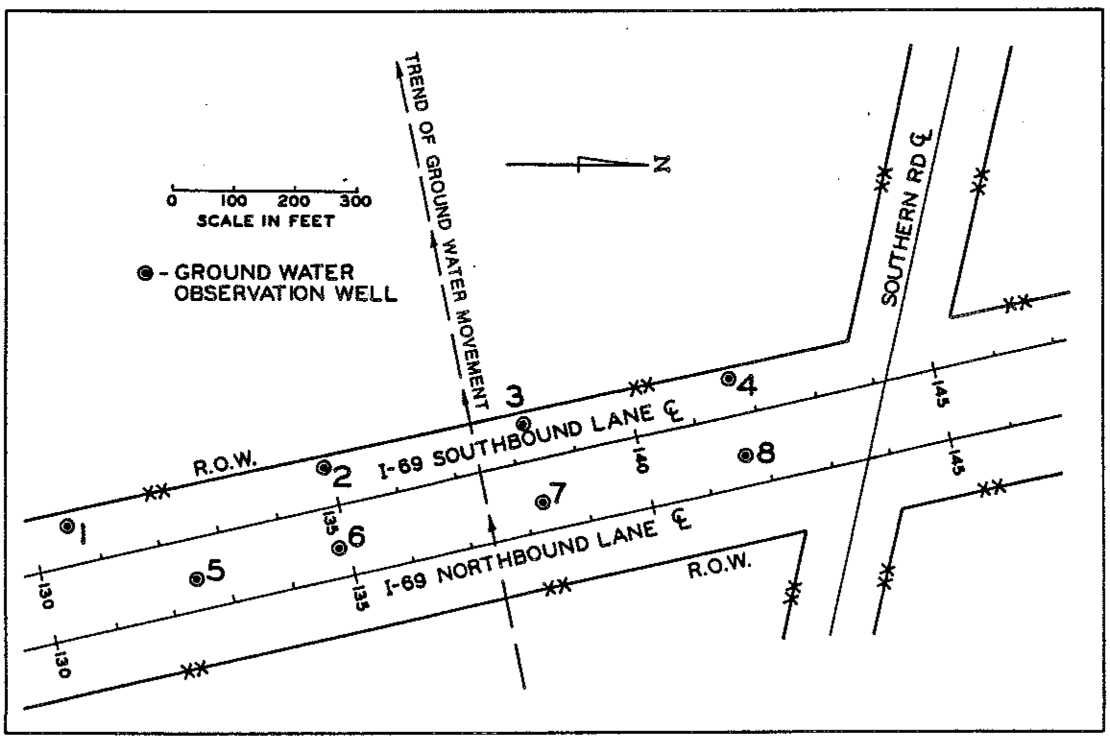


Figure 5. I 69 well locations: I 69, Southern Rd area (Sections 10 and 15, T8S-R6W, Kinderhook Twp, Branch Co.). Roadway opened to traffic in 1967.

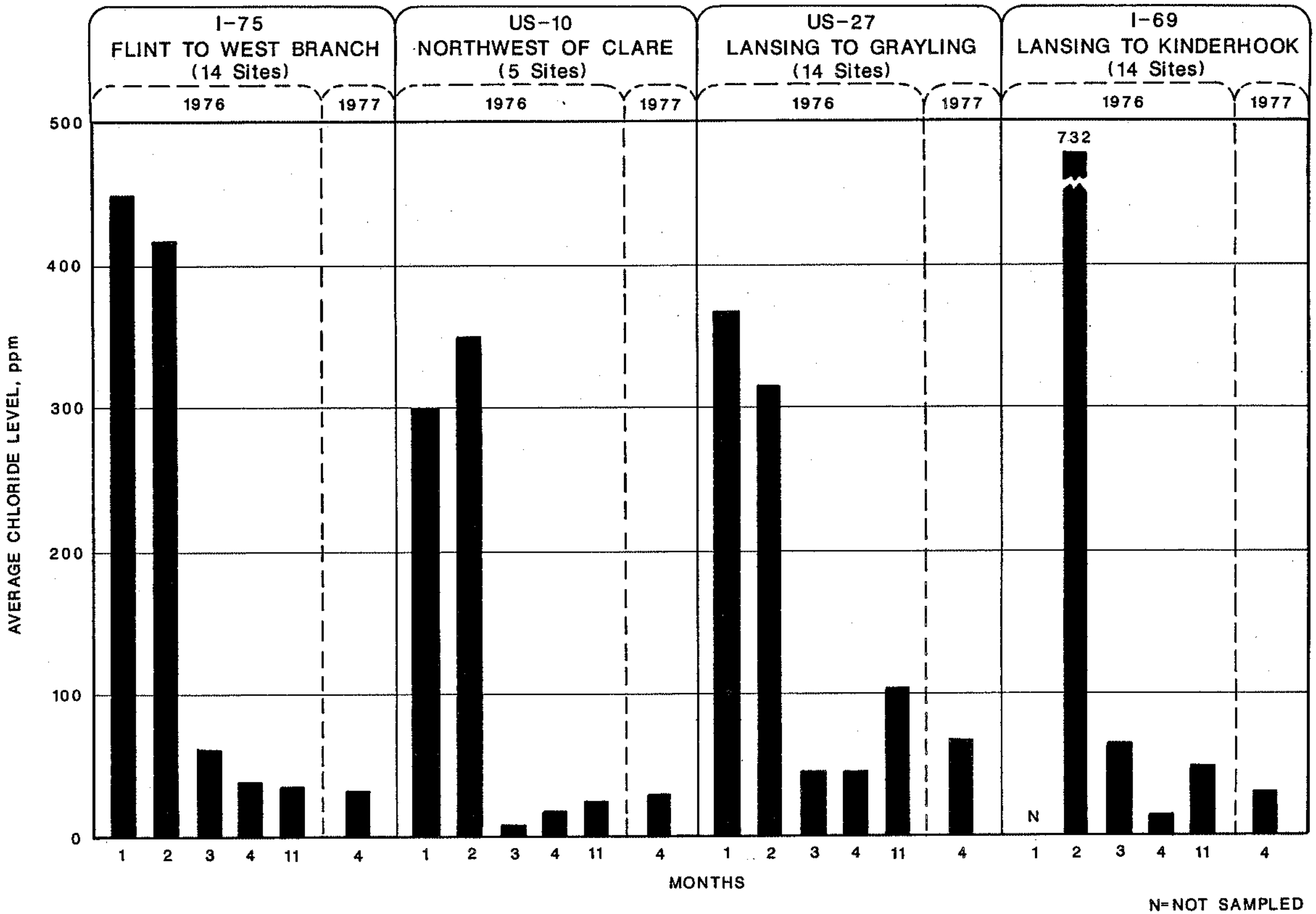


Figure 6. Monthly average chloride levels in shoulder gravel sampled along trunklines.

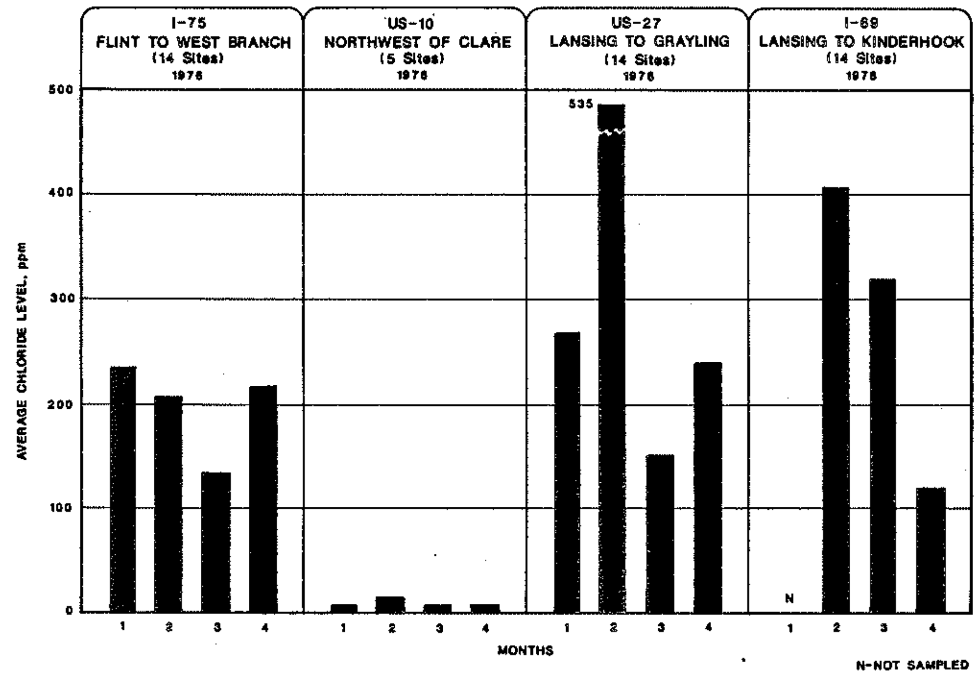


Figure 7. Monthly average chloride levels in roadside ditch and median water sampled along trunklines.

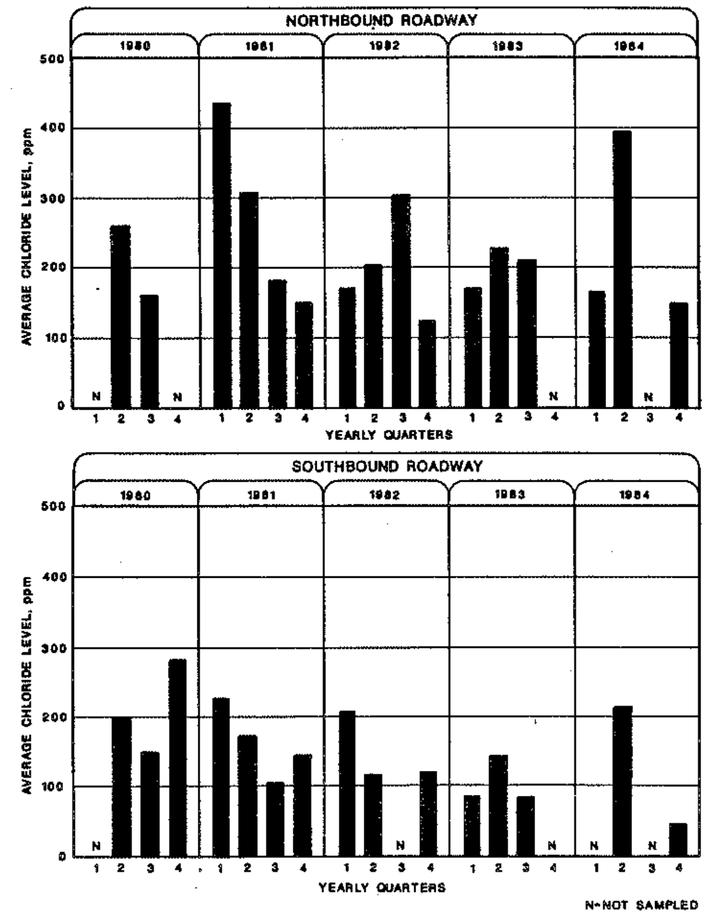


Figure 8. Quarterly average chloride levels in ditch water at Sta. 214+00 I 69 near Kinderhook.

TABLE 1
CHLORIDE LEVELS IN SOILS AT GROUND
WATER MONITOR SITES, AS PPM Cl^-

Ground Water Monitor Well Site	Depth of Sample, in Feet						
	0-1			1-2		2-3	
	July 1976	October 1983	April 1984	October 1983	April 1984	October 1983	April 1984
I 75 Grayling	45	—	—	—	—	—	—
I 75 West Branch	44	4	14	3	12	3	12
US 10 Clare	58	5	18	4	20	5	36
I 69 Kinderhook	46	3	47*	3	42*	2	30*

*Sampled in February due to early thaw conditions.

NOTE: Soil at the I 75 Grayling site was not resampled.

Salt toxicity in soils is described by M. L. Jackson as related to the types of soil and plants (2). Grasses growing in coarse loamy sand similar to roadside soil are indicated as tolerant to chloride levels as high as 600 ppm. Trees and shrubs are indicated as tolerant to 300 ppm.

The average chloride levels in shoulder gravels along the roadways monitored in this investigation were noted to decline below the toxic limit for grasses after the end of the winter seasons. Chloride levels slightly above the toxic limit during the winter period of dormancy do not appear to be harmful.

The low chloride levels in soils at the ground water monitor sites indicate that deicing chlorides are readily dissipated from the roadside environment by dilution in the annual precipitation water.

Surface Waters

Roadside Ditch and Median Water - Water samples were obtained at biweekly to monthly intervals from 47 roadside sampling locations along four trunklines during 1976. Due to dry-up at most locations, sampling was discontinued in late April. One long-term sampling site at a relatively permanent ditch water location was established in 1980 for monitoring through 1984.

Figures 7 and 8 show the results of the samplings. The results indicate considerable variation in chloride levels. The variation reflects the irregular distribution of run-off along roadways, and the complex effects of precipitation and evaporation. Samplings obtained in 1976 along US 10 indicate very low chloride levels. The US 10 roadway was completed in 1975, and had received a small exposure to deicing salt in comparison with the other trunklines which had received years of previous winter maintenance salt treatment.

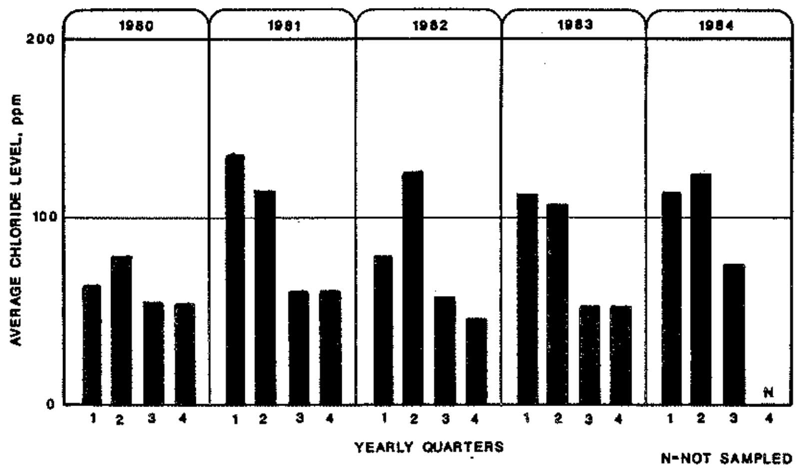
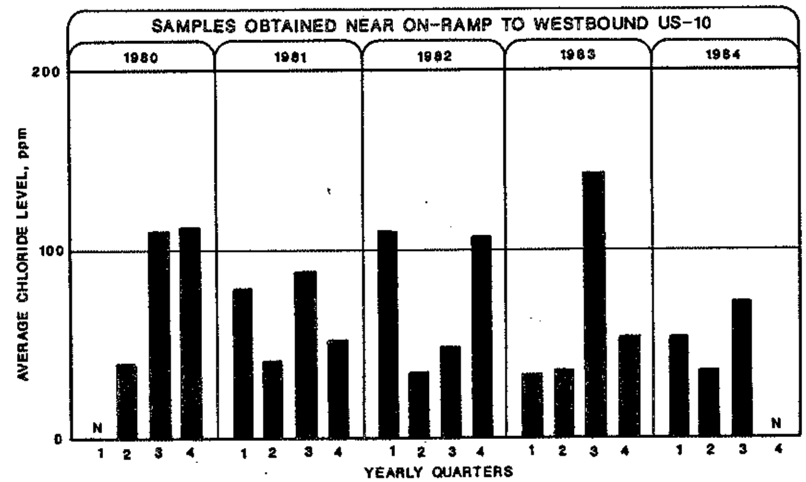


Figure 9. Quarterly average chloride levels in sub-grade water sampled from flowing edge drain at Sta. 145+00 eastbound US 10.



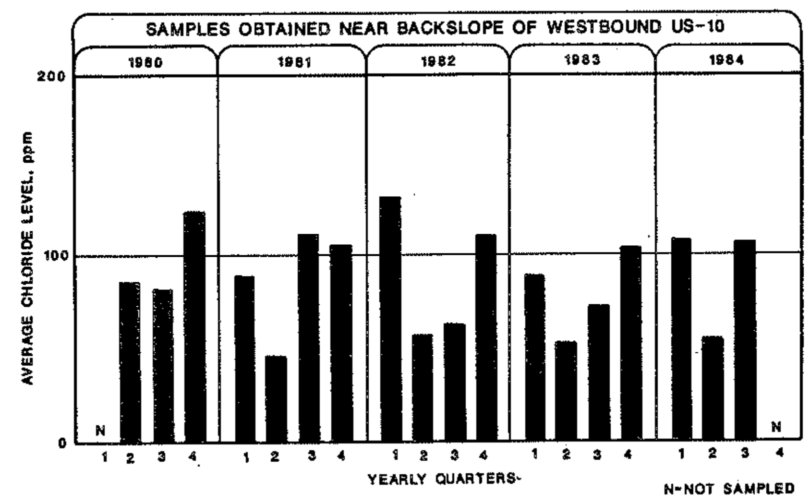


Figure 10. Quarterly average chloride levels in roadside pond at interchange of US 10 and M 115.

The acceptable levels of chlorides in water for animal consumption or habitation are discussed in NCHRP Report No. 91 (7). Safe levels of chloride in drinking water for livestock are noted as 1,500 ppm chloride by the California State Water Quality Control Board, and 5,000 ppm sodium chloride (3,035 ppm Cl^-) by the Australian Department of Agriculture and Government Chemical Laboratories. Monthly average chloride levels monitored along the roadsides during this investigation varied from 7 to 535 ppm, well below the stated allowable maximum.

Edge Drain Water - Water samples were obtained from a constantly flowing edge drain on US 10 during 1980 through 1984. Water from this source accumulated by percolation through the subgrade.

Figure 9 shows the results of the samplings. Variations in chloride content indicate seasonal peaks and declines related to winter maintenance deicing salt application.

Pond Water - A roadside pond along the US 10 trunkline was sampled from 1980 through 1984. The ponded area, less than one acre within the US 10 - M 115 interchange northwest of Clare, was sampled at two locations, at the backslope of the roadway, and at the far end of the pond. Maximum depth in the pond was less than 3 ft.

Figure 10 shows the results of the pond samplings. As in the roadside ditch environment, considerable variation in chloride content is indicated in the shallow pond. This variation appears to be irregular and related to the effects of precipitation and evaporation.

The NCHRP report stated that a chloride level of 4,000 ppm was found to be harmful to bass, pike, and perch. Trout were found to be harmed by a chloride level of 400 ppm. The report also stated that fish food organisms could tolerate chloride levels as high as 3,000 ppm. The monthly average chloride levels in the roadside pond samples obtained for this investigation ranged from 35 to 142 ppm.

Stream Water - Four streams intersecting the trunklines monitored in this investigation were sampled from 1980 through 1984. Water samples were obtained at upstream and downstream locations where the streams crossed the roadways. Figures 11 through 14 include the results of the samplings. The chlorides measured in water samples from the four streams generally varied from less than 10 ppm to 30 ppm.

Background chloride levels in Michigan streams are recorded in "Chemical Quality of Michigan Streams," Geological Survey Circular 634, prepared by the U. S. Geological Survey (8). The natural chloride levels in the streams are indicated from less than 10 to over 40 ppm. The measured chlorides in the streams sampled in this investigation are within the stated background levels, with exception of several isolated samplings from La Porte Creek.

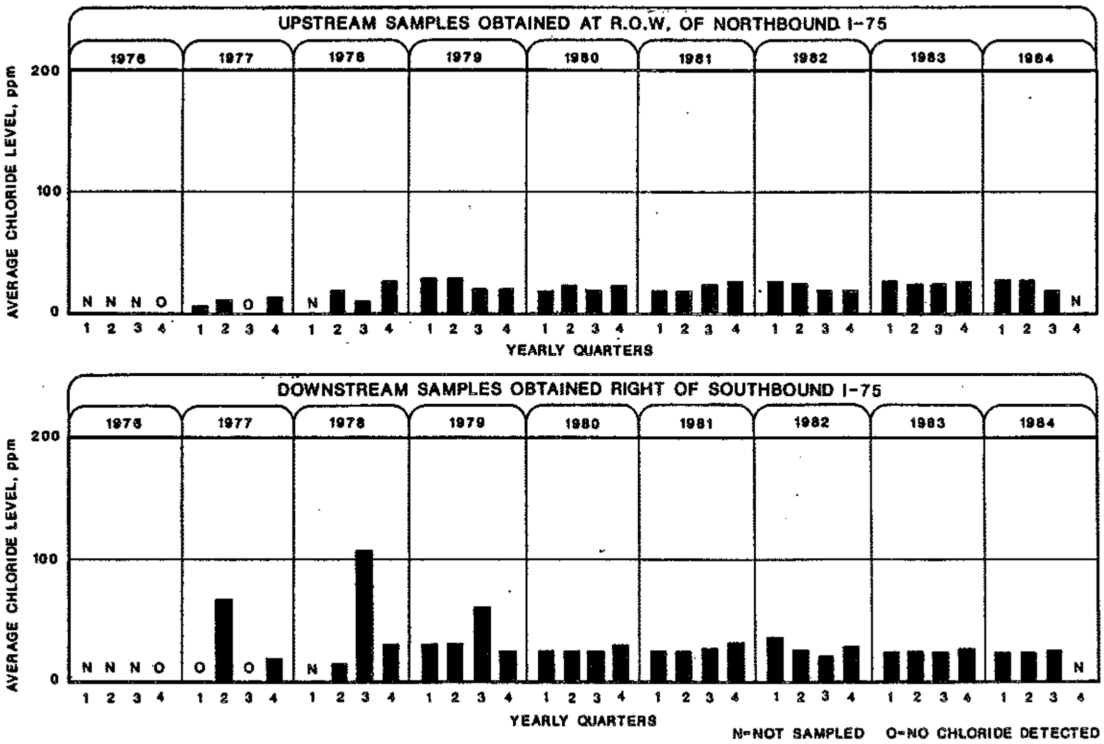


Figure 11. Quarterly average chloride levels in LaPorte Creek at I 75 south of West Branch.

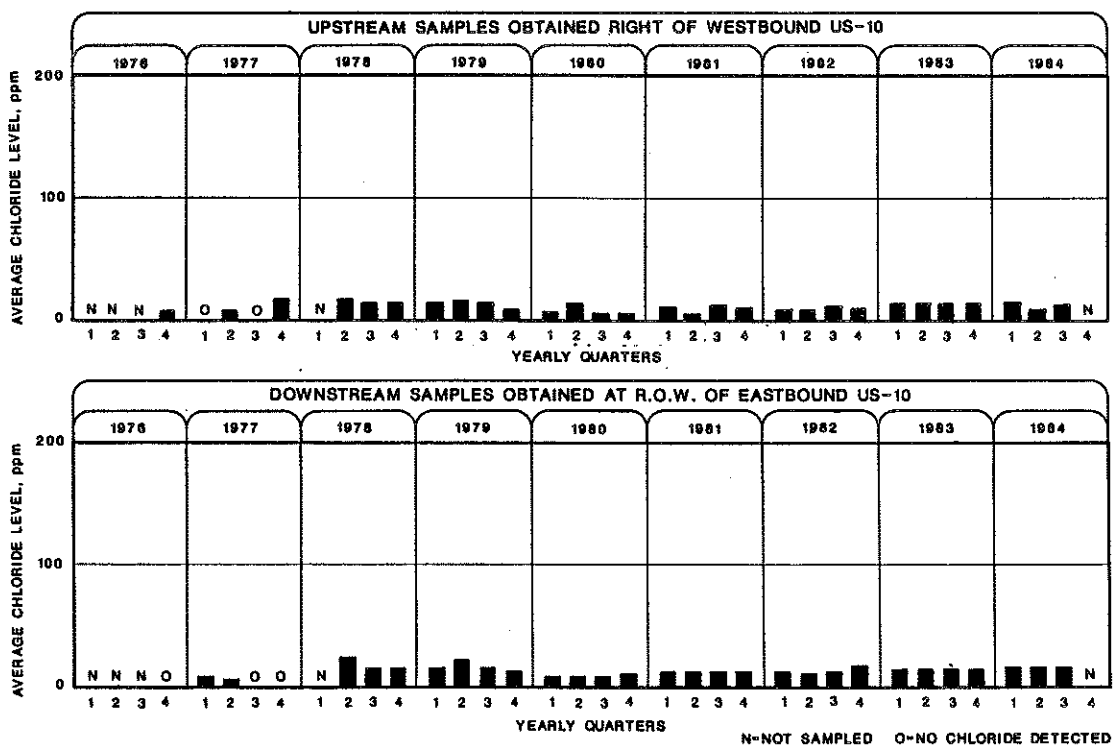


Figure 12. Quarterly average chloride levels in Runyon Creek at US 10 northwest of Clare.

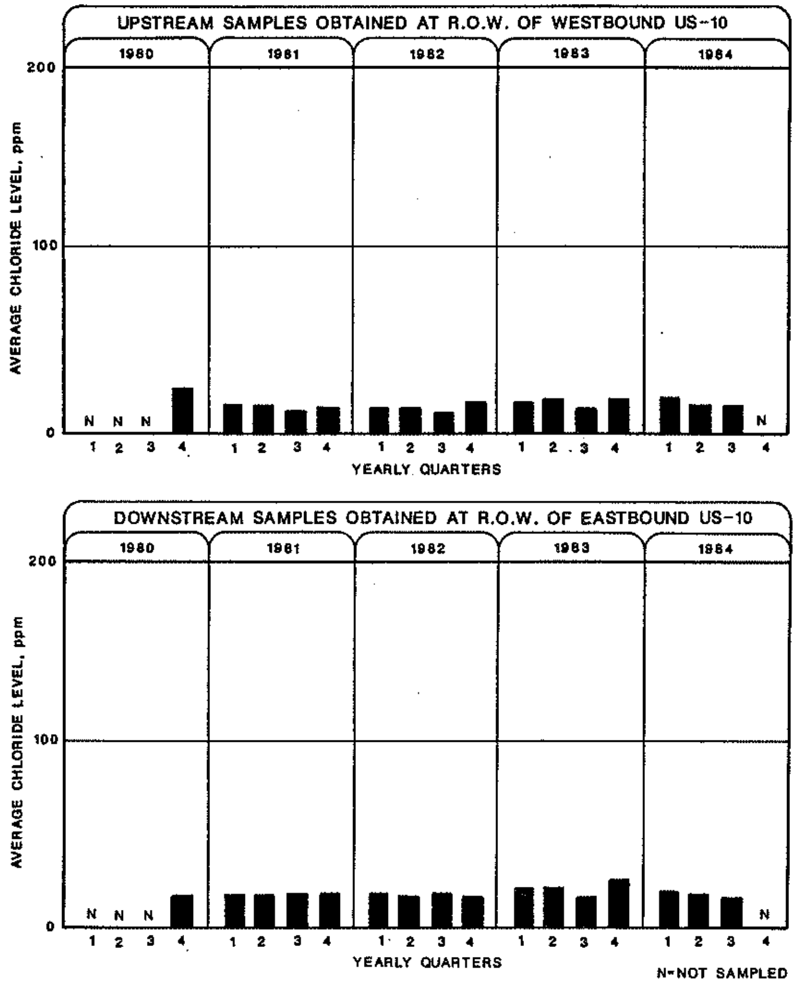


Figure 13. Quarterly average chloride levels in Elm Creek at US 10 northwest of Clare.

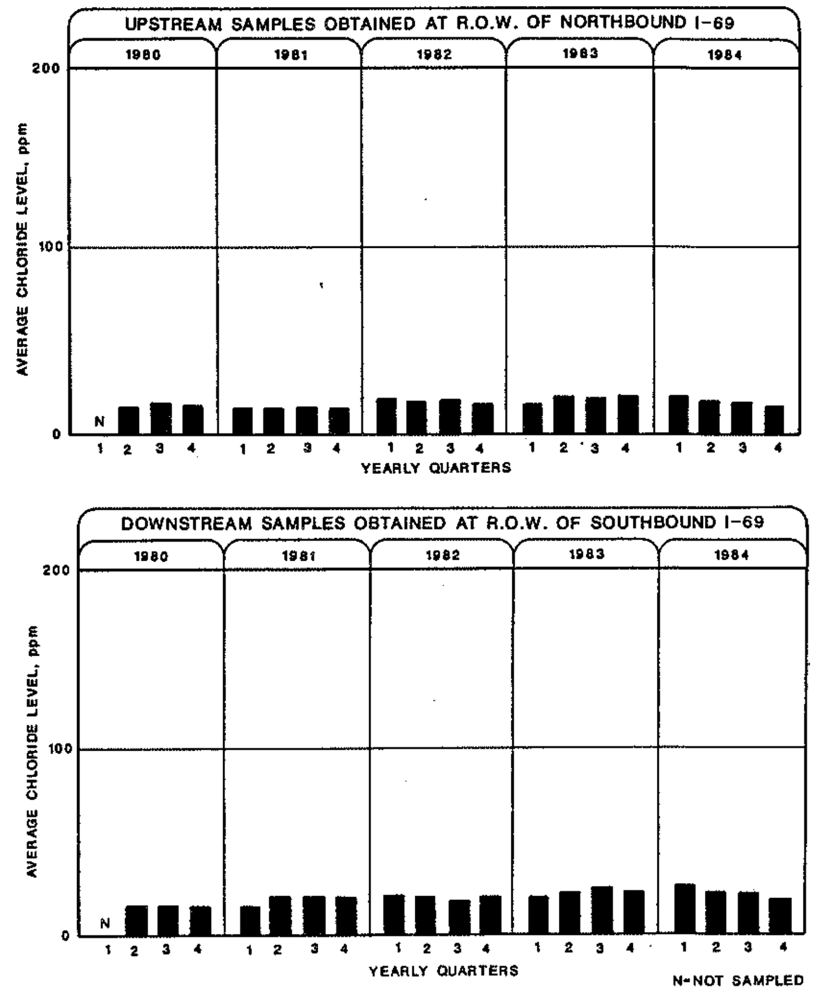


Figure 14. Quarterly average chloride levels in Little Fawn Creek at I 69 near Kinderhook.

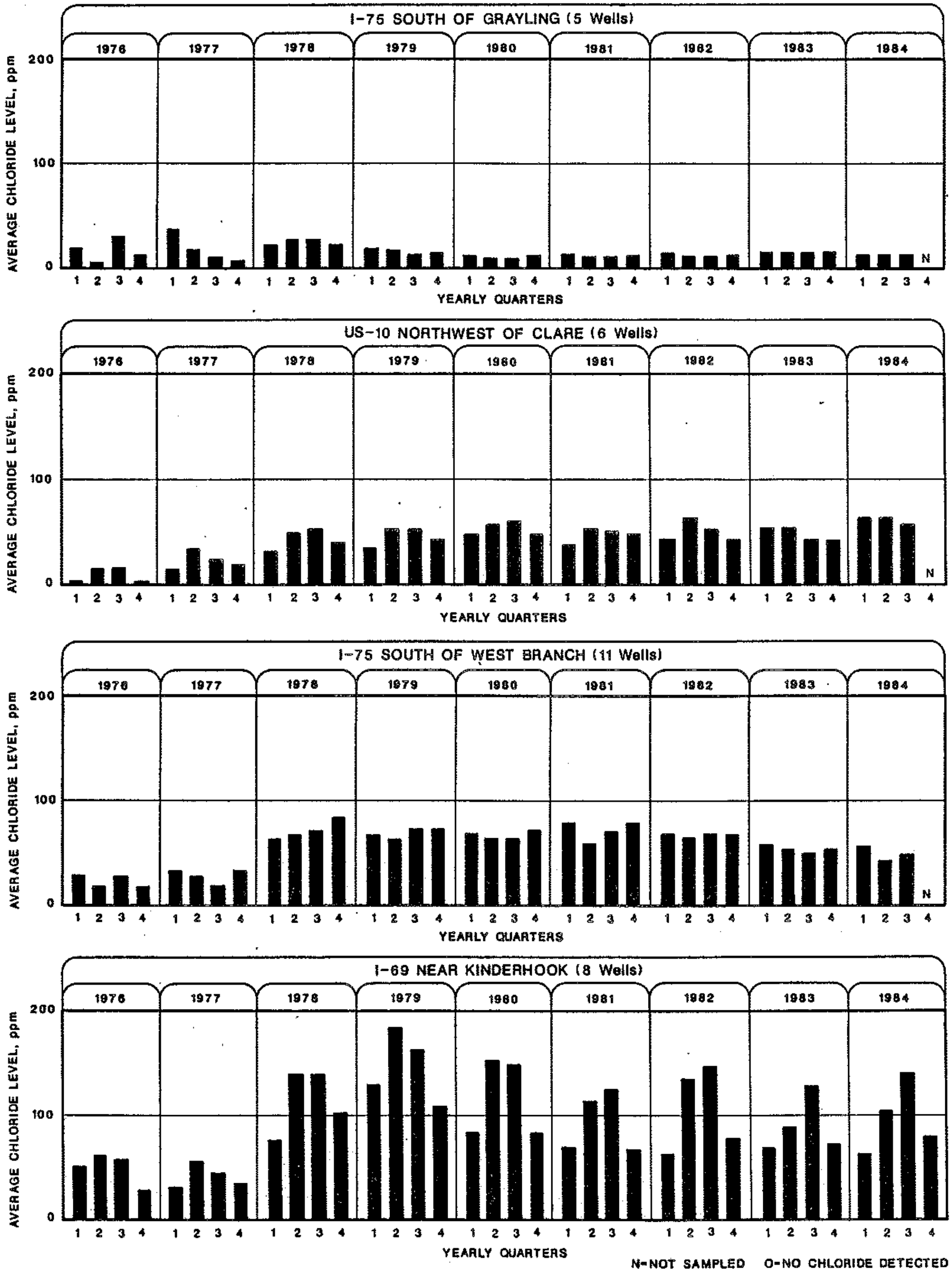


Figure 15. Quarterly average chloride levels in groundwater at well arrays on trunklines.

Ground Water

Results of the long-term ground water monitoring indicate that the roadside ground water chloride levels increase for a few years after the start of winter maintenance deicing treatment on a newly-opened roadway. After the initial increase, a state of equilibrium is reached in which the chloride from roadway deicing is dissipated from the roadside environment at low ground water chloride levels. Figure 15 presents the results of the long-term monitoring at the four ground water sites.

The US 10 samplings provide an example of the change in roadside ground water chloride levels due to the inception of deicing treatment on a new roadway. The US 10 roadway northwest of Clare, opened in 1975. In 1976 it had received only one season of winter maintenance deicing treatment, resulting in very low ground water chloride levels. Samplings in the following years revealed an increase in ground water chlorides to a relatively stable level, indicating that a state of equilibrium had been reached. This pattern is similar at the I 75 West Branch and I 69 Kinderhook sites. The very low ground water chloride levels at the I 75 Grayling site are attributed to the deep water table which permits more complete dispersal of the chloride.

The U. S. Public Health Service drinking water standards issued in Public Health Service Publication 956 set the recommended maximum chloride level at 250 ppm for potable water (9). The average chloride level in the ground water at the four locations monitored in this investigation varied from less than 10 ppm to slightly less than 200 ppm. Although the water from these shallow wells would probably be unfit to drink for other reasons, the water would meet the U. S. Public Health Service requirement for chloride content. Lateral dilution away from the roadside would progressively decrease the chloride content.

Field Observations

The value of visual observation is often overlooked in relationship to the laboratory data obtained in an environmental investigation. Personal observations of the locations from which samples are obtained can often be of help in making interpretations. Throughout the extent of this investigation the field sampling personnel were encouraged to record their observations. A few of the more pertinent field notes are included as follows:

1) Roadside grasses appeared to be healthy along the roadways. Areas of thin cover were usually situated in well-drained, gravelly soil with low content of humic and loamy material necessary for dense turf development. Grasses in the median and along the backslopes developed vigorous growth requiring mowing and did not exhibit the stunting associated with soil toxicity.

2) Potentially salt-sensitive plants, such as trees and shrubs growing along the right-of-way, were often noted to require extensive trimming

to prevent encroachment, and did not exhibit the stunting or wilting associated with soil toxicity. A number of cases of leaf-browning were observed to be due to the use of chemical defoliants along the right-of-way fences.

3) Abundant pond life was observed at roadside surface water sampling sites. Pond water samples required filtering to remove organisms before chloride analysis.

Records of Deicing Salt Usage

At the onset of this investigation an attempt was made to obtain detailed records of salt applications to the roadways during the winter maintenance seasons. Due to the emergency conditions which often dictate winter maintenance plowing and deicing runs, detailed notes of all salt applications at specific locations were not recorded. However, tabulations of regional salt usage were available from the MDOT Maintenance Division. Records of total annual salt usage in the ground water monitoring areas were obtained for the 13 winter maintenance periods encompassed by the investigation (10).

Table 2 gives the recorded salt usages in the localities of the four ground water monitoring sites. The table also includes the statewide average salt usage for comparison. The records indicate a grand average of 20 tons of salt per E-Mile (mile of 24-ft wide pavement) applied per year at the monitor sites. This amount computes to approximately 5 oz of salt per sq ft of pavement per year.

TABLE 2
ANNUAL SALT USAGE, IN TONS PER E-MILE[1]

Winter Maintenance Season	I 75 Grayling Crawford Co.	I 75 W. Branch Ogemaw Co.	US 10 Clare Clare Co.	I 69 Kinderhook Branch/ Calhoun Co.	Statewide Average
1971-72	17.8	17.6	29.1	25.5	26.9
1972-73	18.4	22.7	26.8	26.5	26.4
1973-74	20.2	22.8	18.2	14.6	24.2
1974-75	23.3	26.4	24.5	25.3	26.3
1975-76	19.1	19.6	20.9	19.6	24.1
1976-77	21.5	18.0	19.1	19.9	23.4
1977-78	13.8	19.3	16.2	18.6	23.7
1978-79	15.7	19.7	24.5	23.1	24.9
1979-80	20.0	16.5	17.3	18.2	20.2
1980-81	20.3	22.8	20.0	17.0	22.1
1981-82	18.6	19.2	18.7	21.0	25.7
1982-83	19.0	19.7	20.2	9.6	14.8
1983-84	23.1	20.0	22.4	18.4	27.4
AVERAGE	19.3	20.3	21.4	19.8	23.9

[1]An E-Mile is an equivalent mile of 24-ft wide roadway. Salt usage data obtained from MDOT Maintenance Division records.

The salt usage in the ground water monitoring localities is slightly below the statewide average due to the selection of the rural, undeveloped locations to minimize the interference of ground water chlorides from sources other than roadway deicing salt. The grand average of 24 tons per E-Mile applied statewide would be expected to result in a slightly higher ground water chloride level than measured at the monitor sites.

Records of Precipitation

Precipitation records for the period monitored in this investigation were obtained from National Oceanic and Atmospheric Administration climatological summaries of data recorded at weather stations in the vicinities of the ground water monitoring well arrays.

Table 3 includes the total annual water equivalent recorded at the selected stations (11). The NOAA records indicate a grand average of 32 in. of water equivalent per year for the 14-year period.

This amount converts to approximately 20 gallons of water for each square foot of land area, resulting in a large dilution factor for the dissipation of the roadway deicing salt residues.

TABLE 3
ANNUAL PRECIPITATION AT GROUND WATER
MONITOR SITES, AS EQUIVALENT INCHES OF WATER

Year	I 75 Grayling Grayling Sta.	I 75 W. Branch W. Branch Sta.	US 10 Clare Harrison Sta.	I 69 Kinderhook Coldwater Sta.
1971	29.6	30.8	28.4	26.1
1972	30.7	30.2	35.9	34.7
1973	32.7	27.4	34.2	34.1
1974	31.8	27.2	33.7	29.5
1975	40.7	39.2	39.8	41.5
1976	27.4	24.2	31.3	31.2
1977	30.5	27.7	26.2	33.2
1978	29.2	25.4	27.7	31.6
1979	32.8	27.4	26.6	29.8
1980	30.8	27.4	29.9	42.6
1981	28.4	27.4	29.0	43.3
1982	39.4	31.0	33.0	35.4
1983	35.8	35.3	37.2*	35.6
1984	36.2	29.2	35.4*	33.1
AVERAGE	32.6	29.3	32.0	34.4

*Reporting station at Evart. Harrison station discontinued in 1983.

Precipitation data obtained from NOAA records of precipitation at weather stations nearest to the ground water monitoring sites.

CONCLUSIONS AND RECOMMENDATIONS

The investigation addressed the proposed project objectives by monitoring the chloride levels in the surface and subsurface waters adjacent to the roadways, and determining the direction and rate of ground water migration. Results of the monitoring indicated no need for recommendations of remedial treatment at the locations investigated.

The results of this investigation indicate that the chloride applied to the roadways for winter maintenance at the present rates produces chloride levels within the published acceptable limits for the roadside environment.

As indicated by the results of water and soil monitoring along the roadways, the present usage of deicing salt is apparently balanced by the amount of precipitation necessary to prevent accumulation in the roadside environment. Also, the chloride levels in the ground water were found to be acceptably low at present rates of infiltration.

At the present time salt is the least expensive deicing agent available. As an essential mineral for living organisms, common salt is one of the least harmful agents to release into the environment. Complex chemical deicers, which are considerably more expensive, are much more likely to cause environmental problems. Organic deicers, such as urea, are known to cause imbalances in aquatic environments due to nutrient properties which promote uncontrolled growth of undesirable organisms such as algae. Although considerably more expensive than salt, current literature indicates that calcium magnesium acetate (CMA) may be suitable for use in selected localized areas. Experimental work with CMA is under way at this laboratory under a separate research project.

The reduction of deicing salt usage through controlled spreading rates and greater use of sand-salt mixtures for ice control is encouraged to decrease the chloride levels in the roadside environment.

Continued monitoring of the chloride levels at selected sites is recommended to determine the effectiveness of improved ice control practices in reducing the amount of chloride reaching the roadside environment.

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