5-10-2016

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Kenneth Dueker
Portland State University

William A. Rabiega
Portland State University

Bruce Rex
Portland State University

Citation Details

Dueker, Kenneth; Rabiega, William A.; and Rex, Bruce, "Locating Truck Data Collection Sites in Oregon Using Representation Optimal Sampling" (2016). *Center for Urban Studies Publications and Reports*. 97.
https://pdxscholar.library.pdx.edu/cus_pubs/97

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by

Kenneth Dueker, William A. Rabiega, and Bruce Rex

The Center for Urban Studies
Portland State University

Prepared for
The Oregon Department of Transportation

In cooperation with the
Federal Highway Administration
U.S. Department of Transportation

May 10, 1988

The views and opinions in this report are those of the authors and do not necessarily reflect those of the Oregon Department of Transportation or the Federal Highway Administration. This report does not constitute a standard, specification, or regulation.

Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.

4. Title and Subtitle

Locating Truck Data Collection Sites in Oregon Using Representation Optimal Sampling

5. Report Date

May 10, 1988

6. PSU# 75/24;9-262-7355
PSU# 85/107

7. Author(s)

Kenneth Dueker, William A. Rabiega, & Bruce Rex

8. Performing Organization Report No.

9. Performing Organization Name and Address

The Center for Urban Studies
Portland State University
P.O. Box 751
Portland, OR 97207-0751

10. Work Unit No. (TRAIS)

11. Contract or Grant No.

12. Sponsoring Agency Name and Address

Economic Services Unit-Planning Section
Oregon State Hwy Div., Dept. of Transportation
325 13th St. NE, Room 605
Salem, OR 97310

13. Type of Report and Period Covered

Final Report
January 1987-May 1988

14. Sponsoring Agency Code

Contract #9070

15. Supplementary Notes

Milan Krukar was the Project Manager; Loyd Henion was the Project Administrator

16. Abstract

The Oregon Department of Transportation collects data on the performance of the highway system by sampling traffic volume, vehicle classification, truck weights, pavement conditions, etc. The selection of efficient and accurate locations for collecting data is important. This report addresses the larger sampling problem by focusing on locations for collecting truck weight data. Sites selected for weight-in-motion/automatic vehicle identification (WIM/AVI) within the Crescent/HELP project are assessed to determine their locational suitability for truck weight data collection. A method, Representation Optimal Sampling (ROS), to aid in site selection is reported here. Sampling configurations of six and twelve station using ROS are detailed. ROS was applied to the Interstate Highway System and was also demonstrated on the Federal Aid Primary Highway System to show how ROS could be applied to networks with thousands of segments.

17. Key Words

Trucks, Data Collection
Weigh-in-Motion,
Sampling, Traffic, Sites

18. Distribution Statement

No Restrictions

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	31 plus Exec Summary	

Form DOT F 1700.7 (8-72) Reproduction of form and completed page is authorized

EXECUTIVE SUMMARY

The Oregon Department of Transportation collects data on the performance of the highway system by sampling traffic volume, vehicle classification, truck weights, pavement conditions, etc. The selection of efficient and accurate locations for collecting data is important. This report addresses the larger sampling problem by focusing on locations for collecting truck weight data. Sites selected for weight-in-motion/automatic vehicle identification(WIM/AVI) within the Crescent/HELP project are assessed to determine their locational suitability for truck weight data collection. A method, Representation Optimal Sampling(ROS), to aid in site selection is reported here. Sampling configurations of six and twelve station using ROS are detailed.

ROS differs from the random sampling procedure guidance provided in the HPMS Manual and Traffic Monitoring Guide in two respects. First ROS allows a search of highway segments to identify the subset of segments that meet the minimal engineering criteria for effective placement of monitoring equipment. Segments are also weighted by characteristics, such as pavement condition and average speed, which should increase the likelihood sites exhibiting favorable engineering characteristics are selected. Second, distances between segments are used in a computerized location/allocation algorithm which selects sampling sites that are optimally configured to spatially represent a highway network. The algorithm yields locations that minimize the aggregate distance of all segments to the sampling sites.

Two ROS sampling configurations of six truck data collection(TDC) sites for the Oregon Interstate highway network(228 segments) were compared to a configuration of six selected by ODOT staff using engineering judgment. When all six TDC sites were selected by the ROS algorithm, three of the six were on I-5 and the other three were on I-84. The ODOT selections included four sites on I-5, one on I-84, and one on I-205. Since three of the ODOT sites, two on I-5 one on I-205 are already being implemented, a second ROS run was executed with those locations fixed into the solution. In this second run three TDC sites, one on I-5 and two on I-84, were added to the three predetermined sites. Of the three new sites, one coincided with a site selected by engineering judgment. Use of ROS results in a more evenly distributed set of TDC sites over the total Interstate system. Nevertheless, the three sets selected wholly or partly by engineering judgment reflect criteria for integration with other Crescent states not among those provided for in the ROS procedure. The ROS configurations are superior for representation of the Oregon system alone, whereas the ODOT sites supported an integrated I-5 WIM/AVI coverage over Washington, Oregon, and California.

It was established by an analysis of a range of solution sets that twelve TDC sites would provide spatially efficient coverage of the Interstate System. Thus, three ROS sampling configurations of twelve TDC sites were generated. The configuration that includes six ODOT judgment sites performs nearly as well as the configuration wholly selected by ROS. This configuration includes six I-5, five I-84, and one I-205 stations.

A sample of 38 for a rationalized Federal Aid Primary highway system, was drawn to demonstrate how ROS can be applied to networks with thousands of segments.

The recommended ROS configuration of twelve TDC sites for the Interstate System was compared to samples of twelve randomly drawn from the 228 Interstate segments. ROS samples are unique, hence not fully amenable to standard confidence interval analysis. Yet, the recommended ROS sample had a mean segment average daily truck traffic of 4988.3 compared to the 228 universe mean of 6137.6, a difference of 1149.3 trips. Of 100 randomly drawn samples of twelve, 36 percent had means lower than 4988.3 and another 21 percent had means more than 1149.3 above the universe mean. Of the 100 samples there were only two in which all twelve segments drawn were feasible for WIM/AVI sites according to slope criteria derived from the HPMS file. All ROS samples are screened according to these criteria before they are drawn. Random sampling, then, would likely produce inferior estimates of the mean truck traffic per highway segment and almost certainly require substitution of sites on ad hoc criteria with undeterminable consequences to the integrity of the sample.

INTRODUCTION

The Oregon Department of Transportation(ODOT) is constantly gathering information about the use of highway systems for enforcement of regulation, planning, and design purposes. The Crescent or Heavy Vehicle Electronic License Plate(HELP) project, involving installation of weigh-in-motion(WIM) and automatic vehicle identification(AVI) is one example of a major data collection program that requires the siting of equipment. The purpose of this research is to recommend data collection locations for the HELP project that will also serve as a part of a larger statewide system of sites for collecting truck weight data. The work includes development of a technique called Representation Optimal Sampling(ROS). ROS is a possible alternative for the current sampling guidance provided in Highway Performance Monitoring Field Manual(USDOT, 1984. Hereafter referred to as the HPMS Manual) and the Traffic Monitoring Guide(USDOT, 1985). Using ROS the study identified possible WIM/AVI monitoring locations on the Oregon Interstate system and the Federal Aid Primary Highway system. This report elaborates Representational Optimal Sampling and applies it to generate configurations of sites that satisfy various objectives. Properties of ROS are reviewed through evaluation of those configurations for truck weight data collection on the Oregon Interstate Network.

CURRENT FEDERAL GUIDANCE ON SAMPLING

There is current federal guidance on two aspects of sampling in the HPMS Manual and Traffic Monitoring Guide-sample size and sampling procedure. Size recommendations are based on standard formulas for calculating the error inherent to summary statistics for samples. These depend on the size of the universe and the distributional qualities of the statistics being reported.

The sampling procedure outlined is a random one, with some explicit and implicit stratifications attached to the classifications required for reporting. In it the highway network is divided into discrete observation units, i.e., highway segments. These segments are assumed to be independent, essentially treated as balls in an urn, and randomly drawn without replacement until the required sample size is attained. While a minimum of bias in selection of the sample is insured by a random approach, there is no assurance that the highway segments in a sample will be technically feasible for monitoring, that they will be useful for enforcement purposes, that the data derived will relate to historic sites of data collection, or that resultant data can be coordinated with sets other than HPMS, such as Crescent/HELP. The sample may also have gaps or redundancies in its spatial coverage.

THE REPRESENTATION OPTIMAL SAMPLING APPROACH

Although the ROS approach does not directly address the issue of sample size(ultimately resource limitations will govern sample size), it offers an alternative sampling approach which is designed to maximize representativeness on spatial and engineering criteria. In general, sample selection procedures should provide for both a degree of randomness and representativeness appropriate to a given analytical problem(Stuart, 1976; Williams, 1978). The ultimate goal is that a sample should portray the referent set(universe) from which it was derived. In the absence of other information, the best way to obtain precise estimates is to execute a pure random draw. However, if one knows something about the structure of the universe, the precision of estimators from the sample can be enhanced by stratifying the draw(Stuart, 1976).

ROS uses information in the HPMS and other files to eliminate highway segments not suitable as sampling sites on engineering criteria. It optimizes sampling locations over distances, weighted by an index of advantageous engineering criteria, and allows pre-selection of some sites before optimization starts.

How The ROS Is Executed

The ROS requires that the highway segments, as coded in the existing HPMS data base, be converted into a network. ROS employs an optimal location algorithm called ALLOC(Goodchild and Noronha, 1983; Hillsman, 1980; Rushton, Goodchild, and Ostresh, 1973). ALLOC is a public domain computer package commonly used to allocate multiple service sites in a known market, e.g., locating branch banks or schools in a city. In it, the consuming locations are conceptualized as points and the transportation network as line segments between points. Both the demand points and line segments can be weighted. Population is a common weight for consuming(demand) points and travel time is a normal one for line segments. Given a number of service(supply) points, the algorithm will locate them among the consuming points so as to minimize aggregate travel over the entire system.

Executing this algorithm calls for abstracting the transportation network into a graph which illustrates the pattern of service points and the travel times between them. A set of possible service locations are proposed and the algorithm then moves from these proposed sites until an optimal pattern, one which minimizes aggregate weighted travel time, is found.
The universe for the ROS samples drawn here was all Interstate Highway segments in Oregon. The stations being located were for monitoring truck weights, where WIM technology might be used at any or all sites. Each highway segment was conceptualized as a demand point. These road segments were weighted by a composite index which represents technical and institutional criteria which make them attractive for TDC sites using WIM/AVI technology.
With the road segments conceptualized as demand points, there is no literal analogy to the lines that connect points in a location/allocation network. The connections among highway segments represented as a network are, in fact, points. These points can be considered to have no inherent weight, thus be indicative of topological distance. Under such a conceptualization each point of connection has a weight of one. If one travels from a highway segment to one adjacent to it, a

topological distance of one is covered. A path over many highway segments has a topological distance equivalent to the number of segments covered. The topological distance definition attaches importance to given segments only insofar as they are located in the network relative to all other segments; no other weights are deemed pertinent.

Alternatively, travel times, distances, or costs can be important to indicate the magnitude of relative locational differences. Then the value of those variables can be entered into the optimization as line segment weights.

THE OREGON INTERSTATE APPLICATION

TDC sites on Oregon Interstate highways were selected using ROS. This system has a total of 228 HPMS segments in it. Engineering and institutional considerations were reflected in three ways. First, criteria, such as grade, were used to screen highway segments from eligibility as monitoring locations. Second, unusually important segments, e.g. Ports of Entry(POE's), were fixed into solutions. Third, through weighting highway segments according to engineering acceptability, favored segments were more likely to be selected into site configurations. Also, because some HPMS segments are long while others are short, distance weights were used.

Criteria For Exclusion

Each of the Interstate Highway segments has attributes which may limit the engineering feasibility of WIM technology at TDC sites. Two attributes can limit that feasibility absolutely - speed and grade of the segment. The WIM/AVI equipment can be calibrated to various speed levels and will work satisfactorily as long as the actual vehicle speeds remain within those levels. With low average speeds, particularly on Interstate segments, the variability between vehicles is great, so great that it exceeds the calibration capabilities of the equipment. Thus, if a segment's average speed is 25 miles per hour or less it will be excluded from consideration for a TDC site. If the grades are even mildly steep, the accuracy of weight measurements by WIM is compromised; all segments that did not have grades of less than 2.5 percent over a distance of 200 feet in the segment were excluded from eligibility.

Segments Automatically Included

Three segment characteristics were identified as criteria for automatic inclusion in some samples. They were: 1) the segment has an Oregon Port of Entry on it, 2) the segment was previously designated for a WIM/AVI TDC site, and 3) the segment has an existing weigh station on it. Where automatic inclusion was called for, optimization started after a number of sites were fixed. These sites were forced into the solution and could not be moved to improve optimality. In effect, the range of feasible solutions was bounded by fixing locations.

ENGINEERING ACCEPTABILITY INDEX

Seven variables were selected for aggregation into an engineering acceptability index(EAI) and weighted according to their importance(see Table 1). The variables are standardized to score between 0.00 and 1.00, with 1.00 as the more acceptable location. The index is calculated for each highway segment by simply adding the weighted scores on the variables. That is:

$$EAI_j = \sum_{i=1}^{n} w_i A_i$$

where: EAI_j = the engineering acceptability index of highway segment $_j$

w_i = the weight of variable $_i$

A_i = the score for variable $_i$ on segment $_j$

The weights attached to the variables here represent the consensus judgment of selected ODOT staff wherein 5 is the highest possible weight, i.e.,is the most attractive for a monitoring station. At the time these samples were drawn, the SHRP segments were not firmly decided; clearly inclusion of SHRP designation as a weighted variable when that information becomes available would be useful. The index in this study is based on the six variables in Table 1. In the ROS Interstate system configurations, the EAI is used to weight the possible site segments.

Table 1: Variables and Variable Weights in the Engineering Acceptability Index.*

	Variable	Weight
1.	Pavement Condition	1
2.	Average Speed	1
3.	Average Daily Heavy Vehicles	5
4.	Portable Weight Station Facilities	4
5.	Existing Counter Sites	3
6.	Absence of Bypass	4

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*SHRP Segments are recommended for inclusion with a weight of four, if available.

STATISTICS FOR EVALUATION OF ROS SITE CONFIGURATIONS

Two statistics reported in the ROS algorithm are useful in comparing the network coverage provided among ROS configurations. The first is termed the "mean distance travelled." This reports the average distance of highway segments to the nearest selected site within a given configuration of optimal sites. Among configurations of the same number of sites, that with the lowest mean distance traveled provides the best system coverage. The second statistic is the "maximum distance travelled." This reports the mileage of the most distant highway segment from the selected site to which it is assigned. The best configuration among those with a given number of sites is one in which this number is minimized. These statistics will be reported on the Interstate network ROS configurations detailed below.

ROS SAMPLES

The following series of ROS samples identify selected configurations of six and twelve sites with varying numbers of stations fixed for inclusion. Each solution reports the number of TDC sites and their location by highway and milepost of HMPS segment designation.

Sampling Configurations with Six Sites

Because six sites are already selected for WIM/AVI implementation, configurations of that number are of particular interest. Two samples, ROS I and II, give perspective on the six ODOT station locations selected by engineering judgment. The ROS

I solution has no fixed locations, i.e. all six sites are selected by the algorithm. The ROS II solution has three fixed locations, mileposts 14.96 and 244.46 on I-5 and 24.88 on I-205, representating sites being implemented currently. Table 2 shows the ODOT selections, ROS I, and ROS II by segment highway and milepost. Figures 1, 2, and 3 show ROS samples I, II, and the ODOT sites, respectively.

While the three configurations do not replicate one another, there is great similarity among them. ROS I and II differ in that when the three sites are not fixed into the solution, two of the alternative sites on I-5 are drawn further from the State's southern boundary and closer to the northern boundary. On I-84 the third site is drawn to the eastern state boundary. The fixed I-205 site in ROS II is replaced with a site on I-84. The ODOT selected sites and the ROS configurations differ in that ROS I and ROS II include three I-5 and at least two I-84 locations, while the ODOT selected sites include only one I-84 location. The I-205 site is in both the ODOT and the ROS II configurations, as well as the segment at I-84, mile 108.94. In ROS I, the site at I-84, mile 99.85 was selected by the algorithm. It is adjacent to I-84, mile 108.94 which appears in both the ODOT and ROS II configurations.

The likely reason for these minor discrepancies is that the framers of the ODOT selected configuration included criteria in their selection process that were not reflected in the automatic inclusions and specification of the EAI(Engineering Acceptability Index). For example, ODOT may have desired the I-205 site to capture traffic on the Glenn Jackson Bridge. This reasoning, as

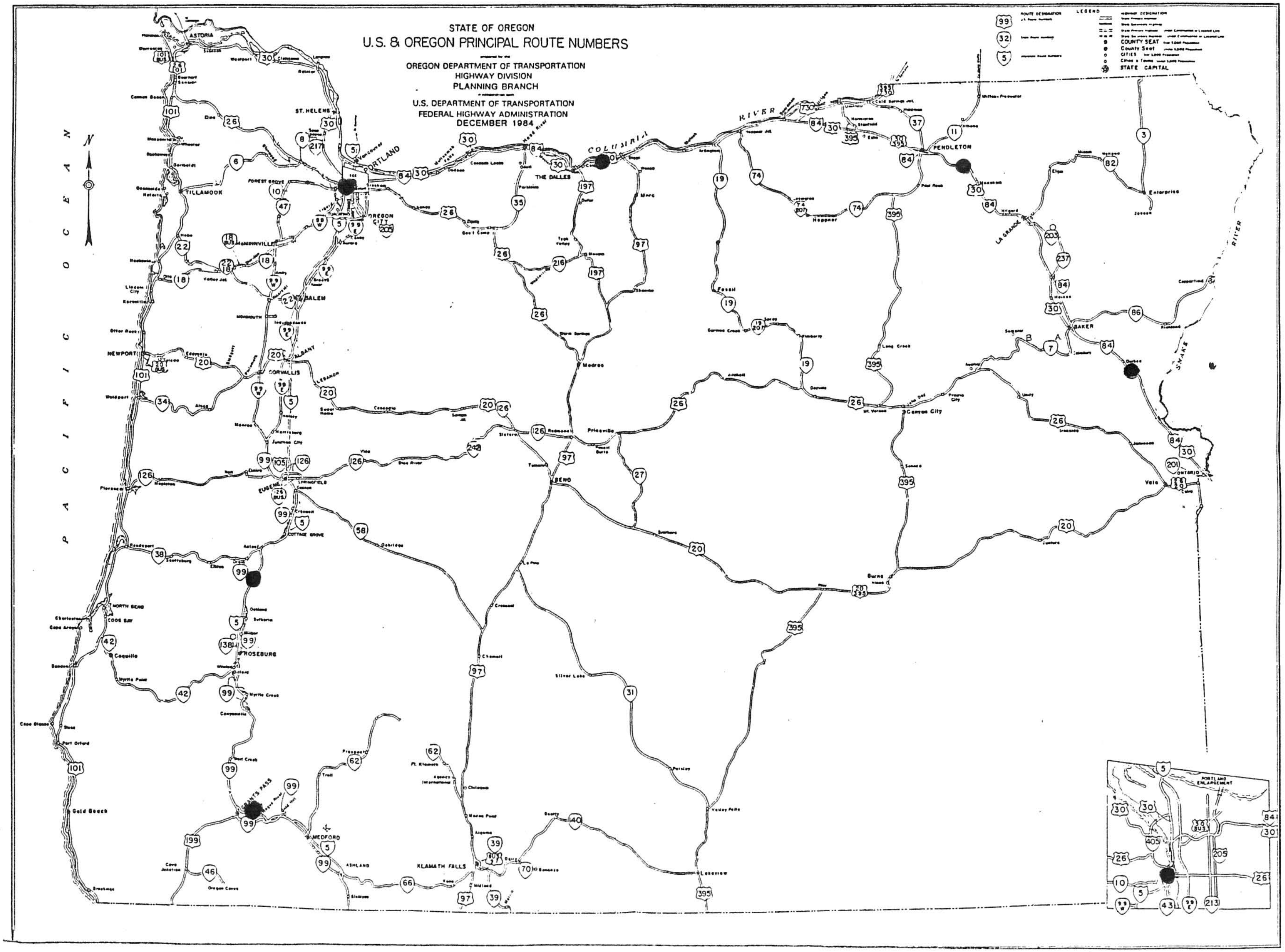

Figure 1 - Six Truck Data Collection Sites on the Oregon
Interstate Highway System: No Fixed Locations (ROS I)

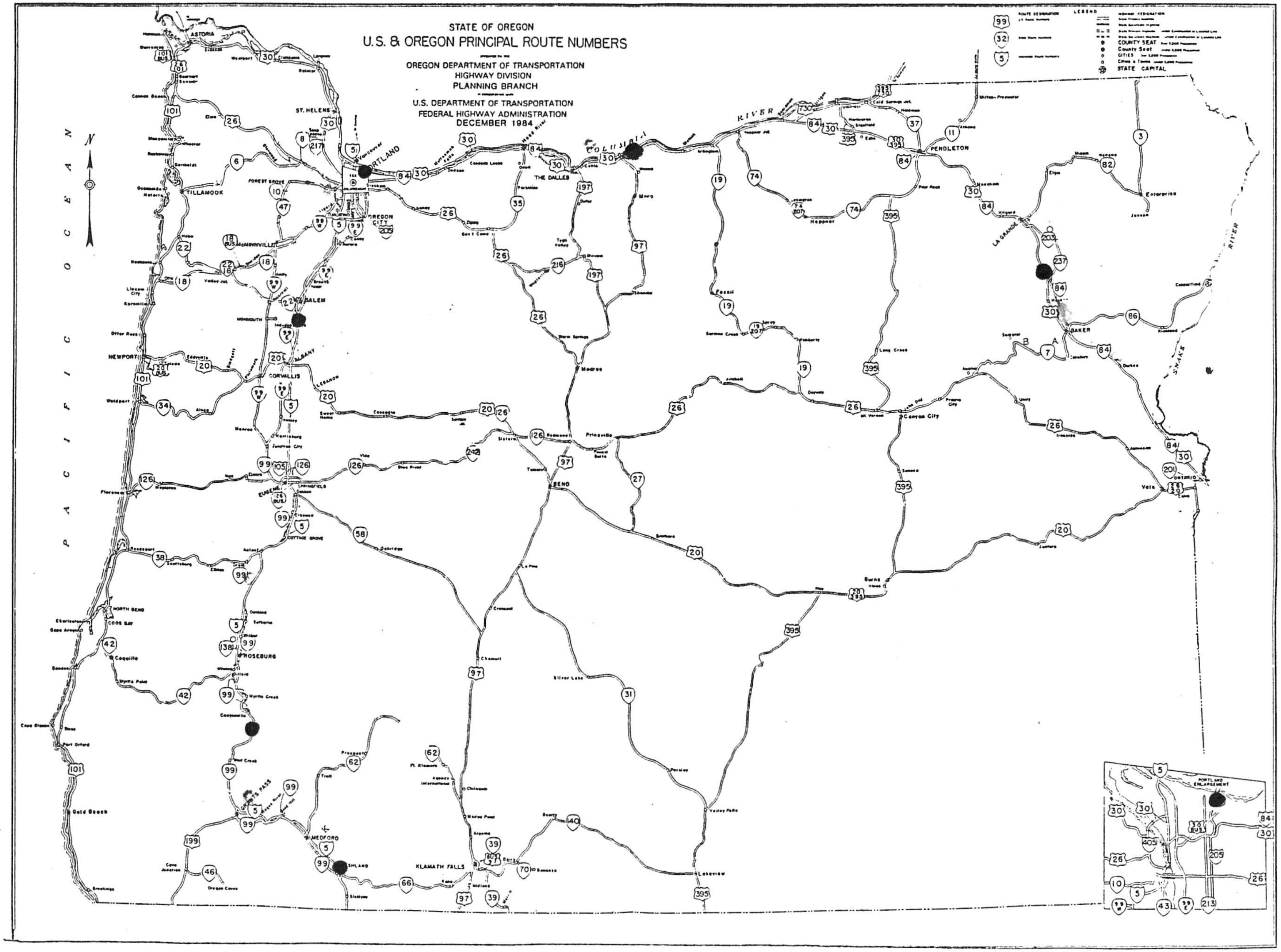

Figure 2 - Six Truck Data Collection Sites on the Oregon Interstate Highway System: 1988 WIM/AVI Sites Fixed (ROS II)

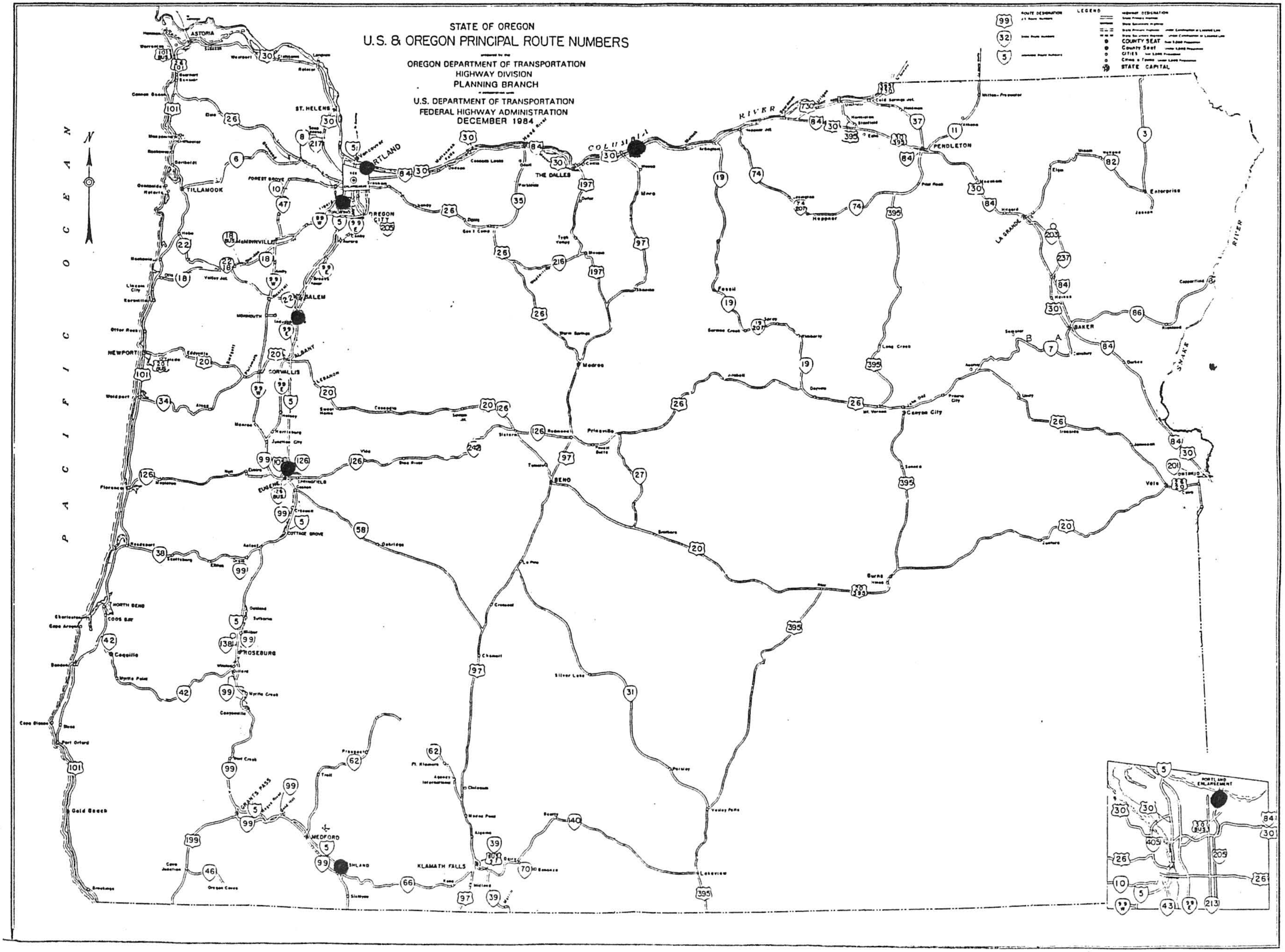

Figure 3 - Six Truck Data Collection Sites on the Oregon Interstate Highway System: Sites Fixed by Engineering Judgment

part of an effort to coordinate Oregon sites with those in the other Crescent Project states of Washington and California, could also account for the greater emphasis on I-5 sites in the ODOT selected configuration. These criteria were not integral to the ROS selections. They could be included by adding variables to the EAI or fixing sites.

Table 2 shows that ROS I, with no fixed sites, achieves the best coverage of the Oregon Interstate network, with an average distance of 22.82 miles. In the ODOT configuration, that mean slips to 24.14. ROS II, with three fixed sites has a average distance of 23.98. The ODOT configuration also shows the greatest maximum distance to a sampling site of 72.92 miles. The difference in the mean and maximum distances among the two ROS and ODOT configurations are not great, but some coverage optimality is clearly lost with selection done totally on consensus judgment.

Sampling Configurations with Twelve Sites

Configurations of twelve stations are of future interest. A sample size of twelve has an efficiency significance which will be detailed in a later section. Three samples, ROS III, IV, and V, illustrate options for this size configuration. ROS III has no fixed sites; it is provided as a baseline for comparison to ROS IV, with I-5, miles 14.96 and 224.46 and I-205, mile 24.88 fixed, and ROS V with all six of the ODOT sites fixed. These configurations are reported in Table 3 and illustrated in Figures

Table 2: Comparison of Configurations of Six Truck Data Collection Sites on the Oregon Interstate Highway System.

	ROS I (no fixed locations)		ROS II (1988 WIM/AVI sites fixed)		ODOT (engineering judgment)	
	Inter-State	Mile No.	Inter-State	Mile No.	Inter-State	Mile No.
	5	55.78	5*	14.96	5*	14.96
	5	154.88	5	99.13	5*	192.86
	5	299.56	5*	244.46	5*	244.46
	84	99.85	84	108.94	5*	294.48
	84	226.76	84	285.33	84*	108.94
	84	324.63	205*	24.88	205*	24.88
Average Distance to Sites		22.82		23.98		24.14
Maximum Distance to a Site		71.88		67.16		72.92

*Fixed locations

4, 5, and 6.

The sites listed in ROS V constitute a configuration of sites selected partly by engineering judgment and partly by optimal methods. It is both workable and provides coverage. While this configuration is suboptimal with respect to the average distance and maximum distance travelled criteria, the fixing of the six ODOT engineering judgment sites is deemed necessary for coordination with other states in the Crescent project. Also, given that the basic level of precision for this analysis is at the highway segment, i.e. the algorithm cannot detect distance differences smaller than a whole highway segment, the discrepancies between ROS III, IV, and V are not substantial.

A permanent weigh station at I-84, mile 226.95 and an existing P.O.E. at I-84, mile 353.31 can be substituted for nearby ROS designated sites, without loss of efficiency. Given that the ROS selections were freely generated, such a close replication of existing sites shows good conformance between the algorithm as executed and past engineering judgment. In effect, ROS has served to confirm previous weigh stations locations, insofar as reasonable within the accuracy and precision of the data underpinning the algorithm. The data are arrayed by discrete highway segments as given in the HPMS file. These may be as short as tenths of a mile or as long as 50 miles. The computer routine cannot discern in finer increments than these segments. The engineering judgments were based on an infinitely divisible, though mentally held, data base. That base also included information from field observation not in the ROS data. Fixing the existing weigh stations and P.O.E.'s into a twelve

Table 3: Comparison of ROS Configurations of Twelve Truck Data Collection Sites on the Oregon Interstate Highway System.

	ROS III (no fixed sites)		ROS IV (1988 WIM/AVI sites fixed)		ROS V (ODOT eng. jgmt. sites fixed)	
	Inter-State	Mile No.	Inter-State	Mile No.	Inter-State	Mile No.
	5	27.27	5*	14.96	5*	14.96
	5	66.58	5	66.58	5	66.58
	5	141.00	5	141.00	5	141.00
	5	192.86	5	192.86	5*	192.86
	5	240.66	5*	244.46	5*	244.46
	5	299.56	5	301.91	5*	294.48
	84	42.09	84	42.09	84	42.09
	84	87.01	84	87.01	84*	108.94
	84	140.97	84	140.97	84	159.07
	84	226.76	84	226.76	84	229.67
	84	323.18	84	329.22	84	324.63
	84	374.63	205*	24.88	205*	24.88
Average Distance to Sites		11.33		11.75		12.23
Maximum Distance to a Site		49.31		47.11		53.38

*Fixed locations

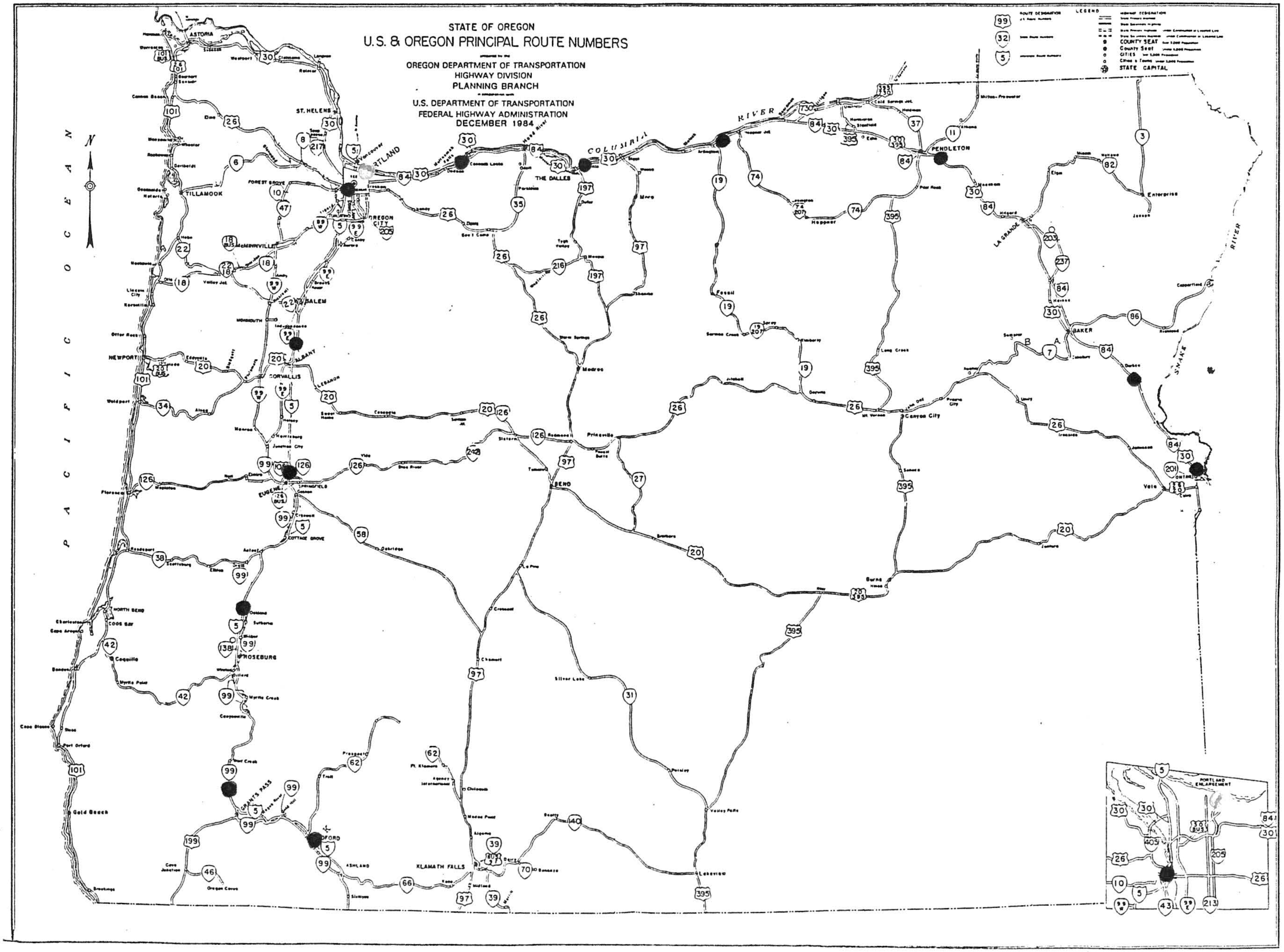

Figure 4 - Twelve Truck Data Collection Sites on the Oregon Interstate Highway Systems: No Fixed Sites (ROS III)

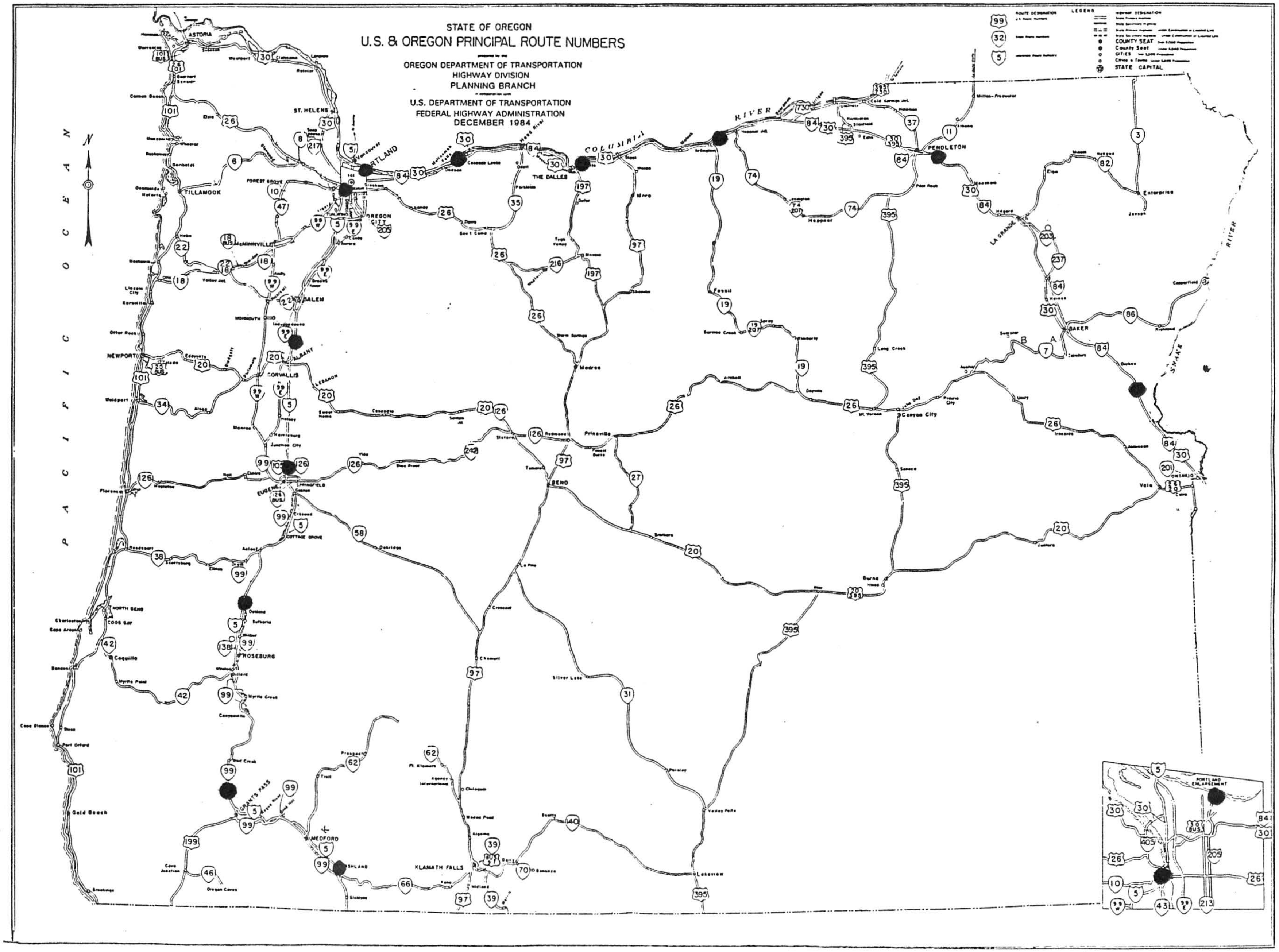

Figure 5 - Twelve Truck Data Collection Sites on the Oregon Interstate Highway Systems: 1988 WIM/AVI Sites Fixed (ROS IV)

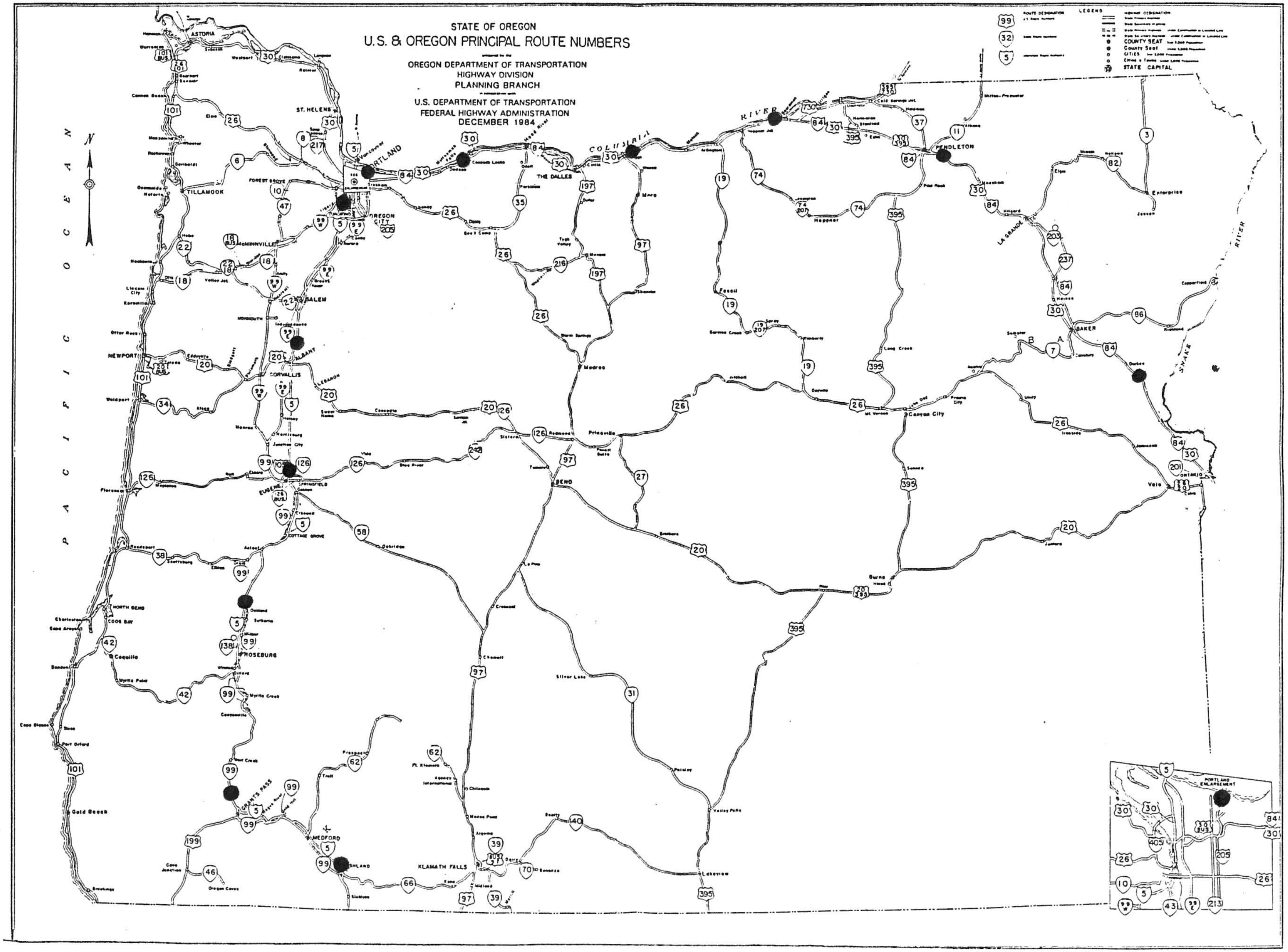

Figure 6 - Twelve Truck Data Collection Sites on the Oregon Interstate Highway Systems: Six sites Fixed by 1988 Engineering Judgment (ROS V)

solution would be appropriate and would produce configurations virtually the same as those already reported.

System Coverage and a Sample Size of Twelve

Figure 7 shows a plot of the relationship of the mean distance from HPMS segments to the nearest truck collection sites for configurations of six to twenty sites. Distance in Figure 7 is expressed as the average number of segments traversed between HPMS segments and the nearest TDC on the Interstate system rather than measured mileage. This allows illustration of the effects of sample size with the network in its most elemental form. The resulting curve shows that mean distance decreases rapidly when the number of sites is increased from six to twelve. Within this range, there is a considerable advantage to adding sites.

However, as the size of the configuration increases from twelve to twenty, the curve flatens. Thus the mean distance does not decrease markedly when sites are added over that range. A configuration of twelve sites for the 228 segments of the Interstate system covers that highway nearly as thoroughly as a twenty site configuration. A configuration of twelve sites is appropriate for the Interstate system.

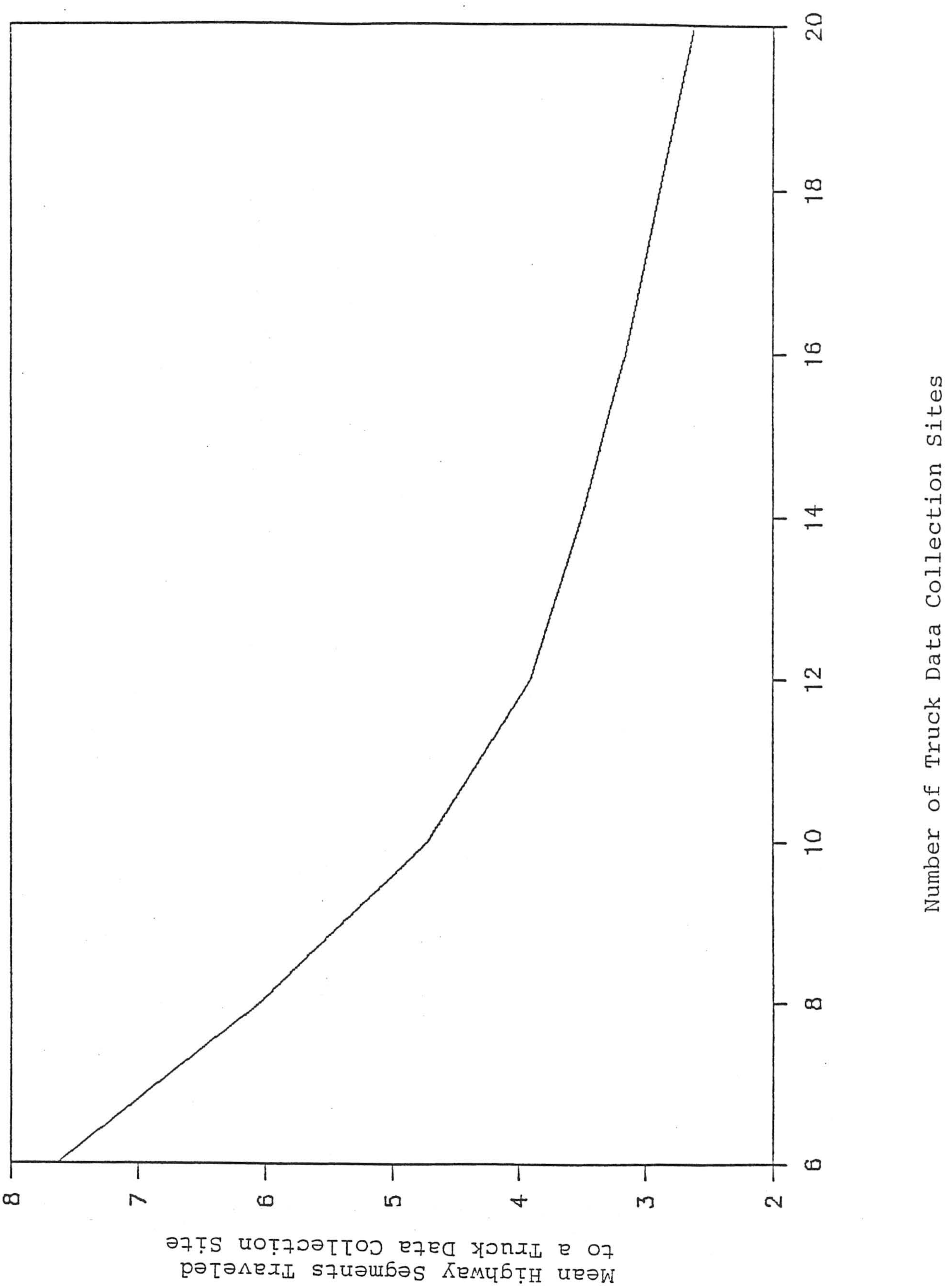

Figure 7 - Mean Distance to Nearest Truck Data Collection Sites for Optimal Configurations of Six to Twenty Sites

LOCATING TRUCK DATA COLLECTION SITES ON AN EXPANDED NETWORK

All federal aid primary highways were included in a second stage analysis. Initially, the combined State Primary and Interstate system had 6249 highway segments. Algorithm limitations required that segments be combined to approximately 600 segments. This was accomplished by combining contiguous segments. Many of these segments have limited data reported for them in the HPMS file, hence an EAI cannot be calculated. Thus, for this run, the segments were weighted by the average daily heavy vehicle traffic only. The mileage definition of distance is also employed, and no segments are excluded on grade criteria. In this example 38 total sites are selected. As data are available, it will be possible to execute samples on the expanded network with all exclusion criteria and a full EAI. The selected locations are reported in Table 4 and illustrated in Figure 8.

PRELIMINARY ANALYSIS OF THE STATISTICAL PROPERTIES OF ROS SAMPLES

A preliminary analysis of the statistical properties of ROS samples was conducted. The analysis was referenced to the recommended ROS configuration of twelve weigh stations(ROS V). The basic question of this investigation was if the ROS approach produced an acceptable estimate of the average truck traffic per highway segment compared to random samples. Usual confidence interval methods are not useful here because they assume means

Table 4: Primary Network(Including Interstate Segments) 38 Site Configuration(ROS VI) with ROS V Locations Fixed.

	Highway Number	Milepost Number
	I-5	14.96
	I-5	66.58
	I-5	141.00
	I-5	192.86
	I-5	244.46
	I-5	294.48
	I-84	42.09
	I-84	108.94
	I-84	159.07
	I-84	229.67
	I-84	324.63
fixed	I-205	24.88
	18	44.46
	19	57.57
	20	1.20
	20	50.11
	20	104.81
	20	173.88
	20	246.52
	26	154.29
	30	59.21
	31	2.31
	35	57.82
	38	0.07
	42	0.15
	62	0.49
	82	1.16
	82	60.12
	97	92.03
	97	121.51
	101	24.93
	101	65.74
	101	105.51
	101	140.51
	101	313.47
	140	5.56
	395	1.63
	395	122.79

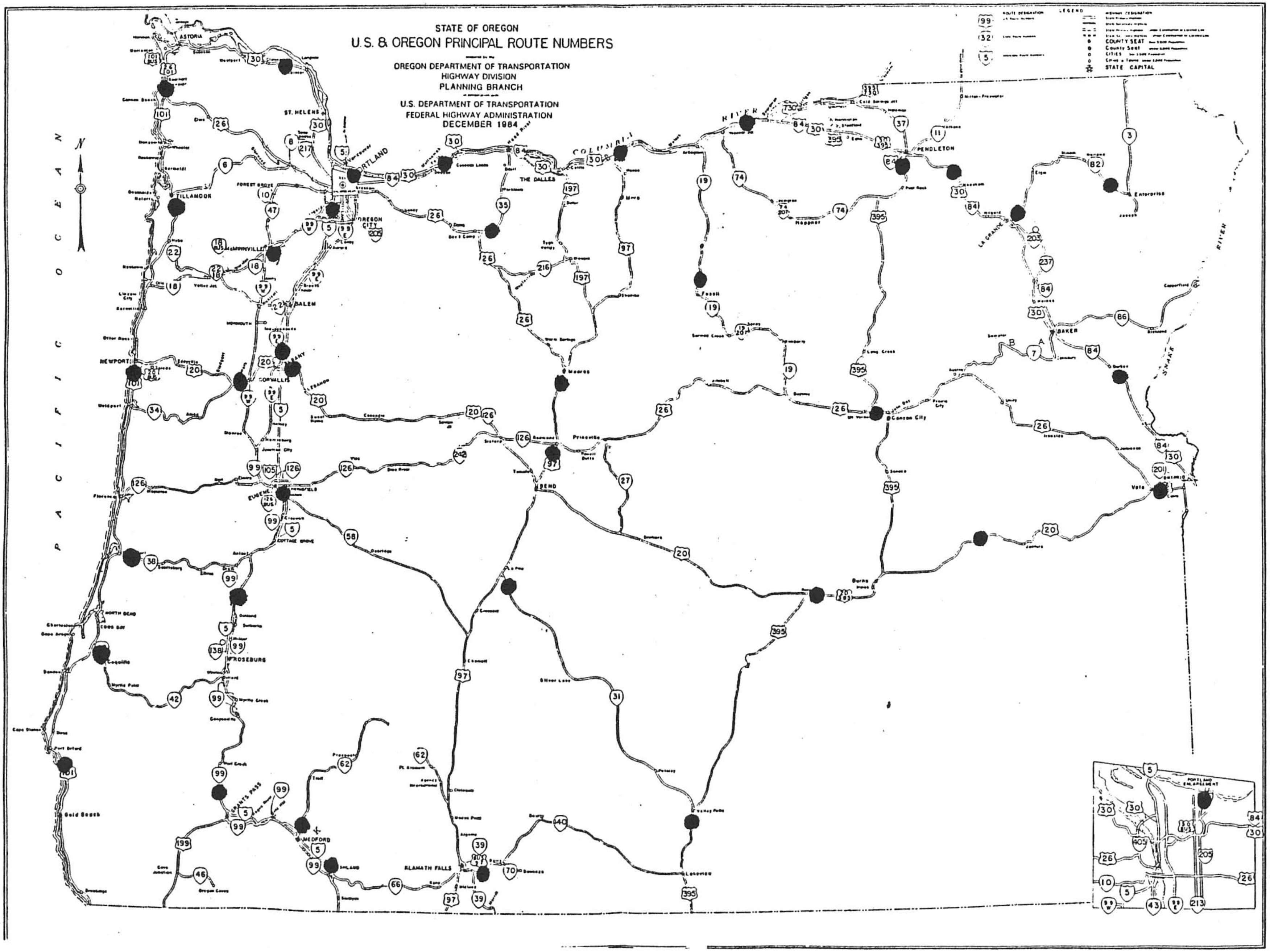

Figure 8 - Twenty-Six Sites Selected on State Primary Highway System with Twelve Sites on Interstate System Fixed

are calculated from an infinity of samples drawn from an infinitely large population. Under such conditions the means can be expected to array in a normal distribution, and the array of sample means around the true mean of the population(universe) can be appropriately described by the standard error of the sampling distribution. That standard error is used to calculate confidence intervals and to decide through using them if a given sample mean is a reasonable estimate of the population mean.

Virtually none of the assumptions needed to apply confidence intervals are valid here. First, each ROS sample is unique. It is optimal within the constraints put on it, and only one configuration can be optimal. Thus sampling variability is not a source of error in ROS samples. Second, the universe here is finite, being comprised of 228 Oregon Interstate highway segments. Third, as will be demonstrated subsequently, it is doubtful if the sampling distribution of means on randomly drawn samples of twelve is normally distributed.

Thus, a sampling distribution for groups of twelve highway segments was approximated by drawing 100 random samples without replacement of that number from the universe of 228 segments and calculating the average truck traffic per HPMS segment for each of the 100 samples. These 100 means were then compared to that of the ROS V configuration. The true mean of the distribution, that for the 228 segments, is 6137.6 vehicles per day. The mean for ROS V is 4988.3, a difference of 1149.3. Of the 100 random samples, 36 percent had means lower than 4988.3 and another 21 percent had means more than 1149.3 above the universe mean. Thus 57 percent of the means of random samples showed a greater increment of error from the true mean than ROS V.

The greater number of low means among the random samples imply the sampling distribution, for groups of twelve with this system of 228 segments, is skewed rather than normal(see Figure 9). Given this condition, a stratification by traffic volume classes is necessary to insure an accurate estimate of the true mean traffic in a single sample.

Finally, when the 100 random samples were screened by the grade eligibility criterion, only two of them had all their members pass that screen. In two cases only five of the members of the sample passed this screen. Thus in 98 percent of those samples, field adjustment of the sample derived sites would likely be necessary. This would, of course, add many elements to sampling site selection which were not systematically expressed and would certainly compromise the scientific attributes of the sample. All members of a ROS configuration are pre-screened by designated engineering requirements, hence should not require adjustment on those grounds after they are named.

In summary, random sampling is likely to show more error than a ROS sample and will almost certainly require adjustment which undermines its scientific validity. Whether this would be true of larger samples within larger networks, is a question which requires additional research.

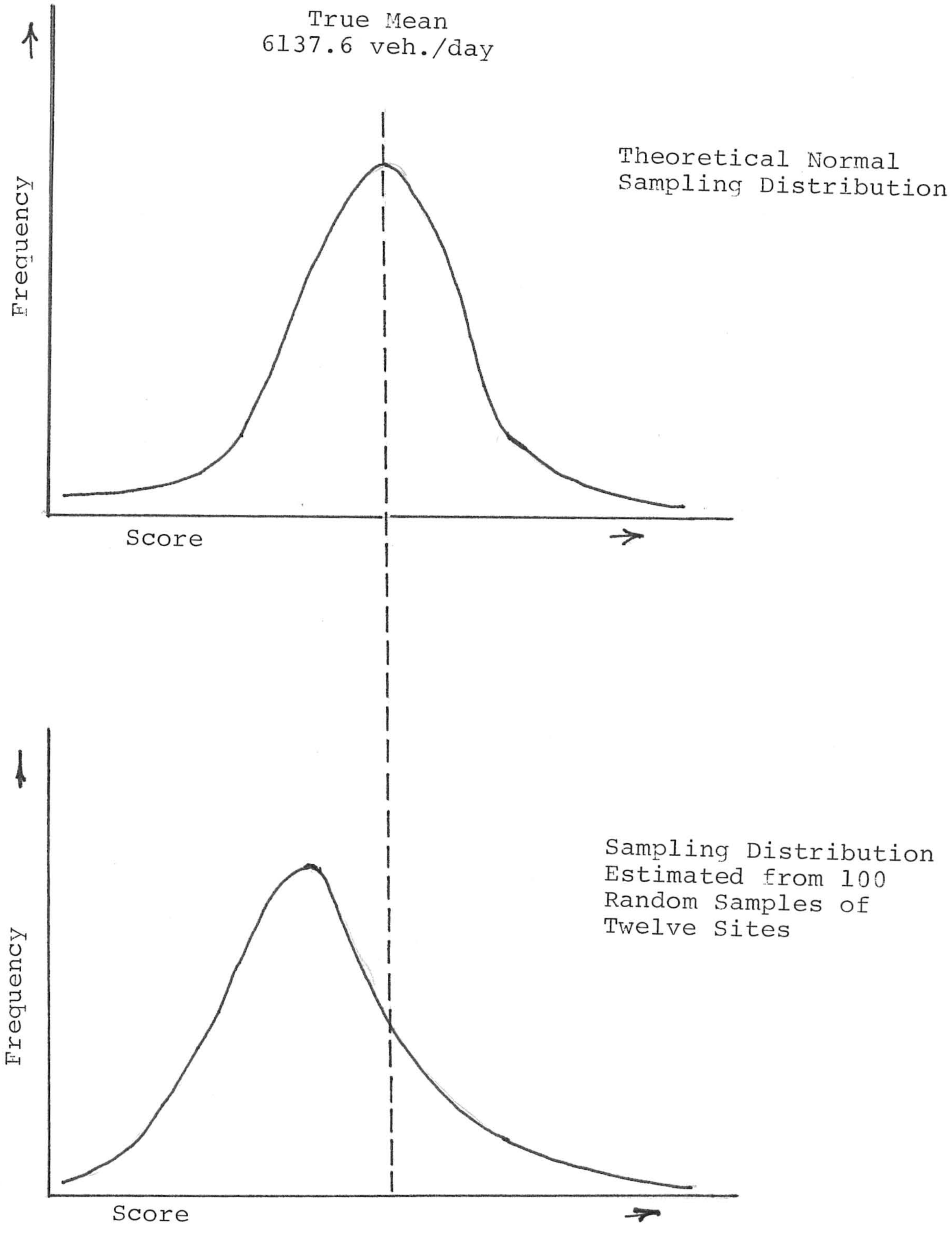

Figure 9: Comparison of a Theoretical Normal Sampling Distribution to a Skewed Sampling Distribution

CONCLUSIONS AND RECOMMENDATIONS

There are several conclusions about the ROS technique which lead to a number of recommendations. The conclusions are:

1. ROS has been implemented successfully at the Interstate level, subject to field site verification.

2. Twelve truck data collection sites efficiently cover Oregon's Interstate highway network of 228 segments.

3. With further development, ROS can be used practically at the Primary highway level, if necessary, desirable, or appropriate.

4. Compared to ROS V, random draws are less likely to produce accurate estimates of truck traffic and will almost certainly include highway segments unacceptable on engineering criteria.

Recommendations include:

a. A twelve site configuration should be selected for collecting truck weight data on the Oregon Interstate system.

b. The twelve site configuration shown in ROS V, which includes the six ODOT engineering judgment sites, is the one which provides good coverage of the Interstate system.

c. Substituting proximate existing POE or existing weigh stations for ROS selected sites does not seriously affect the optimality of ROS sample V.

d. The six ODOT engineering judgment sites are appropriate for implementation as part of the Crescent/HELP project, because of the necessity of coordination with other project states. However, the ROS configurations are the appropriate locations for six truck weigh stations with WIM/AVI if the Oregon Interstate system alone is under consideration. All ROS solutions are specific to the network from which they are drawn.

e. A follow-up project is needed to 1) determine if the same site configurations will result when strictly planning or strictly enforcement criteria are employed, 2) provide an expanded comparison between ROS and random samples on traditional sampling theory principles, 3) enhance programming to draw sampling configurations for large networks, 4) evaluate alternative configurations for truck weight data collection on the Oregon Primary highway system, and 5) evaluate alternative site configurations for traffic volume and vehicle classification sampling on the Oregon Interstate system.

f. ROS recommended highway segments should be field checked for feasibility as truck data collection sites. Grade was the only physical characteristic included in the algorithm that was used to screen HPMS segments.

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