4. ANALYSIS OF GAS DISTRIBUTION SYSTEM OUTSIDE FORCES DAMAGE

The U.S. DOT's recent damage prevention program regulations emphasize what might be called the "one-call process" for gas pipeline damage prevention. That is, while they do not require participation in a one-call program, the regulations do mandate the development of a damage prevention program with many of the more important attributes and characteristics of a one-call system. Understanding more fully the one-call process, its impact on outside forces damage, and the factors affecting it can be a first step toward further improving gas pipeline damage prevention. To develop insights into the operation of the one-call process, in the section that follows, an outside forces damage model for gas distribution system operators belonging to U.S. one-call systems is developed and estimated.

4.1 MODELLING INCIDENT LEVELS

The level of outside forces incidents experienced by gas distribution system operators participating in one-call systems is influenced by a number of factors and conditions. It appears that the most important of these, given the nature of outside forces damage and given the efforts that have been made (and are being made) in the area of damage prevention, can be expected to be (1) the level of exposure to the risk of damage experienced by the underground facilities of gas systems, (2) the provisions of the various damage prevention laws and regulations extant, (3) the organizational structure and operating characteristics of the gas pipeline operators (since their behavior will help determine the success or failure of their ,one-call-system-based damage prevention programs), (4) the structure and operating characteristics of the one-call systems to which the gas companies belong, and (5) the general trend in incident levels over time. To meaningfully model the level of outside forces incidents, all of these factors and conditions must, in one way or another, be accounted for.

The approach used in modelling incident levels was to specify and estimate a regression equation for gas distribution system operators in one-call systems using data for the years 1980 through 1982 (the most recent years for which incident data by gas distribution system were available at the time of this study). Variables representing all of the major factors influencing the level of outside forces incidents were included in the estimated equation.

The sample used in the estimation of the incident level equation consisted of observations on gas distribution system operators belonging to one-call systems and operating in a state for which starting year information on gas system participation could be obtained for all one-call systems in the state. The participation information employed in setting up the sample was obtained directly from various of the one-call systems in operation in the U.S. at the time of this study. The gas system participation information obtained in the course of this study can be found in Appendix D.

In the sample, a gas pipeline operator operating in more than one state (and supplying the U.S. DOT, in mandatory annual reports[66], with information on each state's operations) was treated as a separate firm for each state of operation. Similarly, a one-call system operating in more than one state was treated as a separate one-call system for each state of operation. Firms operating in two or more one-call systems within the same state were treated as belonging to a special "overlap" one-call system. No attempt was made to identify the gas distribution system operators whose service areas are only partially covered by the one-call system(s) to which they belong. A list of the one-call systems and overlaps with paticipants in the sample can be found in Table 5.

For purposes of this study, all firms reporting annually to the U.S. DOT under 49 CFR 191.11 ("Distribution system: Annual report!') were defined to be operating gas distribution systems. Because the U.S. DOT's damage prevention regulations (see 49 CFR 192.614) exempts "Pipelines to which access is physically controlled by the operator"[67] and "Pipelines that are...part of a distribution system operated by a person in connection with that person's leasing of real property or by a condominium or cooperative association,"[68] firms who report to the U.S. DOT under 49 CFR 191.11 and who appear to come under these exclusions were not included in the sample

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[66]See 49 CFR 191.11.

[67]49 CFR 192.614(c)(3).

[68]49 CFR 192.614(c)(4).

TABLE 5. ONE-CALL SYSTEMS WITH PARTICIPANTS IN SAMPLE

State and System	State and System
Alabama	Indiana
MISS ALL	INDIANA UNDERGROUND PLANT PROTECTION SERVICE
	UNITED UTILITIES PROTECTION SERVICE
California	
USA NORTH	Iowa
USA SOUTH	UNDERGROUND PLANT LOCATION SERVICE
USA NORTH/USA SOUTH Overlap	
	Kansas
Colorado	KAN-U-DIG-IT
CENTRAL LOCATING UNIT	
	Kentucky
Connecticut	BUD
"CALL BEFORE YOU DIG"	UNITED UTILITIES PROTECTION SERVICE
Delaware	Michigan
"MISS UTILITY" OF DELMARVA	MISS DIG
Florida	Missouri
"CALL CANDY"	"TO BEGIN"
CONSTRUCTION CONTROL CENTER	
"CALL CANDY"/CALL U.N.C.L.E./	Nebraska
UNDERGROUND UTILITIES	ONE CALL COVERS ALL
NOTIFICATION CENTER Overlap	
	Nevada
Georgia	USA NORTH
UTILITIES PROTECTION CENTER	
	New Jersey
Illinois	GARDEN STATE UNDERGROUND PLANT LOCATION SERVICE
JULIE	
DIGGER	

TABLE 5. **ONE-CALL SYSTEMS WITH PARTICIPANTS IN SAMPLE** (CONTINUED)

State and System	State and System
North Carolina	Texas
UTILITIES LOCATION CO.	TEXAS ONE CALL SYSTEM
	AUSTIN AREA ONE CALL SYSTEM
Ohio	
OHIO UTILITIES PROTECTION SERVICE	Utah
UNITED UTILITIES PROTECTION SERVICE	BLUE STAKE
	West Virginia
	MISS UTILITY OF WEST VIRGINIA
Oklahoma	
OKLAHOMA ONE-CALL SYSTEM	Wyoming
	CALL-IN-DIG-IN SAFETY COMMISSION
Pennsylvania	SOUTHEASTERN WYOMING UCC
PENNSYLVANIA ONE CALL SYSTEM	CONVERSE COUNTY CC
	WEST PARK UCC
South Carolina	SWEETWATER COUNTY UCC/CARBON COUNTY UCC Overlap
PALMETTO UTILITY LOCATION	CARBON COUNTY UCC/ALBANY COUNTY UCC Overlap
SERVICE	FREEMONT COUNTY UCC/CENTRAL WYOMING UCC Overlap

used in the estimation of the incident level equation. Though the U.S. DOT's damage prevention program regulations also exempt gas pipelines operating in Class 1 and 2, and certain Class 3 locations, and LP-gas systems[69] no attempt was made to identify and remove pipelines meeting these conditions from the sample because of the difficulty involved in doing so.

4.1.1 The Variables

The specific variables in the incident level model can be found in Table 6. A primary consideration in the selection of the variables for the model was the availability of data.

4.1.1.1 The Dependent Variable - As Table 6 indicates, the dependent variable of the incident level model (OFIS) is the number of outside forces incidents occurring to a firm during a year. The data for this variable were obtained from the U.S. DOT's computerized gas distribution system annual report databases for 1980-81 and 1982.[70] These databases contain

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[69] 49 CFR 192.614(c)(1), (c)(2), and (c)(4). For definitions of Class 1, 2, and 3 locations, see 49 CFR 192.5(a), (b), (c), (d), (f)(2), and (f)(3).

[70] U.S. DOT, Hazardous Materials Information System computerized databases. The databases from which these data were taken needed considerable "cleaning up" before the data could be used. The first step in the process was to add usable gas distribution system operator names and identification numbers to records containing no name (or an obscure name) and no operator identification number (or a completely unique number). Records that could not be matched with a gas system operator were dropped from the sample. Records with a usable operator name but no operator identification number were augmented with a usable identification number. The next step in the process was the removal of (1) all but one record in sets of duplicates, (2) obviously incorrect records for which obvious corrections were not readily apparent (where obvious corrections were apparent, they were made), and (3) all records in sets in which the records appeared to be for the same operator and the same operating region (and, of course, the same year), but did not agree in their reported number of dig-ins. Sometimes, multiple records for the same operating system, operating region, and year agreed on dig-ins, but not on reported pipeline mileage and/or number of services. In many, if not most, cases, a comparison of pipeline mileage or number of services over time indicated that one particular record was more likely than the others to be correct. In these cases, this record was kept in the sample and the others were dropped. When a comparison over time did not indicate a most-likely-correct record, all records in the set were dropped from the sample. The final step of the "clean up" was to make certain that the records for operators operating in multiple states were associated with the appropriate state of operation, not the headquarters (or some other) state. To accomplish this, the dataset was examined, and records linked with inappropriate states were identified and changed, while records for multiple or unidentifiable states were removed from the sample set.

TABLE 6. **VARIABLES USED IN THE MODEL**

Category and Variable	Description	Measure
	DEPENDENT VARIABLE	
OFIS	Outside forces incidents	incidents per year
	INDEPENDENT VARIABLES	
Exposure Measure Variables		
CONSTN	Construction contracts let in state during year	billions of 1982 dollars
PIPE	Gas distribution pipeline mileage plus estimated service pipe mileage in service region	miles of pipe
POP	Estimated population of one-call system service region	number in thousands
State Damage Prevention Law Variables		
DLAW1	Dummy variable indicating whether state of operation has damage prevention law	1(= law exists) or 0(= no law)
DLAW2	Dummy variable indicating whether state has legal requirement that utilities must respond to all excavation notices	1(= required by law) or 0(= no requirement)
DLAW3	Dummy variable indicating whether state law mandates participation in a one-call system	1(= mandated) or 0(= not mandated)
Gas Company Variables		
DSIZE1	Dummy variable for gas companies reporting less than 101 services	1(if true) or 0
DSIZE2	Dummy variable for gas companies reporting from 101 to 1,000 services	1 or 0

TABLE 6. **VARIABLES USED IN** THE MODEL (CONTINUED)

Category and Variable	Description	Measure
Gas Company Variables (Cont.)		
DSIZE3	Dummy variable for gas companies reporting from 1,001 to 10,000 services	1 or 0
DSIZE4	Dummy variable for gas companies reporting from 10,001 to 100,000 services	1 or 0
DSIZE5	Dummy variable for gas companies reporting from 100,001 to 1,000,000 services	1 or 0
DSIZE6[a]	Dummy variable for gas companies reporting more than 1,000,000 services	1 or 0
DGOVT	Dummy variable indicating if the gas company is government owned/ operated	1(if govt) or 0
One-Call System Variables		
PAR	Number of underground operators participating in one-call systems	number of firms
RTIME	Time requested by one-call system between notification of system and start of excavation	hours
INCALLS	Calls made to one-call system	number of calls
ADBUD	One-call system advertising budget for year	1982 dollars
CALLPOP	Calls made to one-call system per system telephone operator per year	number of calls per operator
DOPTYPE	Dummy variable indicating whether system is a contract or in-house operation	1(= contract) or 0(= in-house)

TABLE 6. **VARIABLES USED IN THE MODEL** (CONTINUED)

Category and Variable	Description	Measure
One-Call System Variables (Cont.)		
DSCOVER1[a]	Dummy variable indicating system is statewide	1(= statewide) or 0(= not statewide)
DSCOVER2	Dummy variable indicating system is not statewide but state is completely covered by one-call systems	1(= is the case) or 0(= not the case)
DSCOVER3	Dummy variable indicating system is not statewide and areas of state are not covered by a one-call system	1(= is the case) or 0(= not the case)
DNEWSYS	Dummy variable for new one-call systems	1(if new system) or 0
Year Variables		
D1980[a]	Dummy variable for 1980	1(for 1980) or 0
D1981	Dummy variable for 1981	1(for 1981) or 0
D1982	Dummy variable for 1982	1(for 1982) or 0

[a]Dummy variable implicit in constant term of equation.

the information submitted to the U.S. DOT by gas distribution system operators as required by 49 CFR 191.11. This report must be submitted annually by all gas distribution system operators, including all petroleum gas system operators except those serving "less than 100 customers from a single source."[71]

One-call systems, and the one-call process, are designed to assist in the prevention of excavation damage. One-call systems can be expected to have little or no impact on outside forces damage resulting from non-excavation-related causes, such as earthquakes, land subsidence, the weather, or vandalism, which appear to account for somewhere around 50 percent of all outside forces incidents.[72] As a consequence, it might be expected, given the impetus for this study, that the number of excavation incidents occurring might be a more appropriate dependent variable for the incident level model than the total number of outside forces incidents. Unfortunately, there was no data source that could supply reliable figures on the level of excavation damage at the firm level (or even at the one-call system level), nor was there any data source that could be used to generate reliable estimates.

4.1.1.2 The Independent Variables: Overview - The independent (or explanatory) variables of the incident level model, as can be seen in Table 6, include three exposure measure variables, three state damage prevention law variables, seven gas company variables, ten one-call system variables, and three year variables.

4.1.1.3 The Independent Variables: Exposure Variables - The three exposure measure variables included in the model are CONSTN, the value of construction contracts let during the year in the state in which the gas distribution system operates, PIPE, the estimated mileage of gas system pipe, and POP, the population in the service region of the one-call system in which the gas distribution system participates. All three of these exposure measures

[71] 49 CFR 191.11(b).

[72] Based on information obtained from the U.S. DOT's computerized gas pipeline leak report databases, which are part of the U.S. DOT's Hazardous Materials Information System.

are expected, a priori, to vary directly with the level of incidents. That is, an increase in any one of these variables is expected to result in an increase in the number of incidents that occur, since the more exposure to the risk of an accident, the more accidents, all other things equal.

The exposure variable, CONSTN, was derived from data taken from the STATISTICAL ABSTRACT OF THE UNITED STATES (see Table 7 for the value of construction contracts let by state and year from 1980 through 1982). The deflator used to put the construction figures into 1982 constant dollars was the Department of Commerce composite construction cost index,[73] with the base year changed from 1977 (the base year of the reported data) to 1982.

PIPE, the second exposure variable, was derived by adding the total mileage of mains of a system to the number of services of the system times 50 feet, the estimated average length of a service,[74] divided by 5280 feet. Mileage of mains and number of services were obtained from the U.S. DOT's computerized gas distribution system annual reports.

The third exposure variable, POP, was estimated by multiplying the total population of the state of operation of the gas system of interest by the percentage of the total state population in a year residing in the one-call system's service region. The state population data used were taken from the STATISTICAL ABSTRACT OF THE UNITED STATES, 1984. The percentage figures used in the derivation of POP were obtained primarily from the "One-Call Systems Directory."[75] For the one-call systems in the sample for which no percentage figures were given, estimates were calculated using the coverage information contained in the "One-Call Systems Directory" and the population data taken from the 1980 U.S. Census.[76]

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[73] See the STATISTICAL ABSTRACT OF THE UNITED STATES, 1984, p. 739.

[74] Courtney, Kalkbrenner, and Yie, p. 31.

[75] "One-Call Systems Directory," for 1981-92 and 1983-84.

[76] U.S. Census, 1980 CENSUS.

TABLE 7. VALUE OF CONSTRUCTION CONTRACTS BY STATE
1979 THROUGH 1982
(In Billions of Constant 1982 Dollars;
States Are Those In Which Work Was Performed)

State	Year 1980	1981	1982
Alabama	2.1	1.9	2.0
Alaska	0.8	1.2	1.5
Arizona	3.4	3.2	3.8
Arkansas	1.4	1.3	1.6
California	19.0	17.5	15.4
Colorado	3.0	4.5	4.1
Connecticut	1.6	1.9	1.6
Delaware	0.3	'0.6	0.4
D. C.	0.5	1.0	0.8
Florida	13.8	12.3	10.8
Georgia	4.2	3.9	5.0
Hawaii	1.3	0.9	0.9
Idaho	0.7	0.7	0.5
Illinois	5.7	4.8	4.7
Indiana	3.0	3.0	2.9
Iowa	1.7	1.3	1.3
Kansas	2.0	1.3	1.4
Kentucky	2.4	3.5	2.7
Louisiana	3.5	3.9	5.7
Maine	0.6	0.4	0.5
Maryland	3.3	2.5	3.0
Massachusetts	2.9	3.3	2.9
Michigan	4.5	3.3	2.5
Minnesota	3.0	2.7	2.9
Mississippi	1.7	1.4	1.1
Missouri	2.8	2.5	2.4
Montana	0.4	2.1	0.6

TABLE 7. **VALUE OF** CONSTRUCTION **CONTRACTS BY** STATE
1979 **THROUGH 1982** (CONTINUED)

State	Year		
	1980	1981	1982
Nebraska	0.9	0.8	1.0
Nevada	1.3	1.3	1.1
New Hampshire	0.5	0.6	0.5
New Jersey	4.1	3.6	3.7
New Mexico	1.5	1.4	1.3
New York	6.3	6.5	7.1
North Carolina	3.7	3.4	3.4
North Dakota	0.5	0.5	3.1
Ohio	5.6	4.9	4.8
Oklahoma	2.5	2.8	3.1
Oregon	2.1	2.1	1.4
Pennsylvania	5.6	5.0	4.5
Rhode Island	0.3	0.4	0.3
South Carolina	2.7	2.2	2.2
South Dakota	0.5	0.4	0.8
Tennessee	3.0	2.6	2.6
Texas	14.7	17.9	16.9
Utah	1.2	1.8	3.3
Vermont	0.3	0.3	0.4
Virginia	3.7	3.5	3.6
Washington	5.2	3.6	3.4
West Virginia	0.9	0.7	0.8
Wisconsin	2.4	2.1	1.8
Wyoming	0.7	0.6	0.7

Source of construction contracts data: STATISTICAL ABSTRACT OF THE UNITED STATES, various issues; original source of data: F. W. Dodge, DODGE CONSTRUCTION POTENTIALS.

4.1.1.4 <u>The Independent Variables: State Damage Prevention Law Variables</u> - As can be seen in Table 6, the three state damage prevention law variables included among the explanatory variables of the incident level model are DLAW1, DLAW2, and DLAW3. The three, all dummy variables, indicate respectively the existence of a state damage prevention law, the existence of a legal requirement to respond to all excavation notices, and the existence of mandatory one-call participation. Since the purpose of the damage preventions laws is, of course, the reduction of excavation incidents, the estimated regression coefficients of all three variables are expected to be negative. No Federal regulatory variables were included in the model because OSHA's regulations, the only Federal damage prevention regulations in existence prior to the 1984 effective date of the U.S. DOT's damage prevention program regulations, have not been considered very effective.[77] Local regulatory variables were not included in the model because it appears that the main legislative and regulatory thrust toward damage prevention has been historically at the state level.[78]

A number of possible law variables could have been included in the incident level model (see Table 2). The three selected for the model were chosen to cover the state efforts at damage prevention while minimizing the adverse effects of multicollinearity, a statistical estimation problem caused by highly correlated independent variables that was detected during preliminary work with the model.[79] The information used to create the three state damage prevention law dummy variables (which can be found in Table 2) was obtained primarily from the legal codes of the various states in the sample.

4.1.1.5 <u>The Independent Variables: Gas Company Variables</u> - The gas company variables included in the incident level model consist of a set of company size dummy variables, DSIZE1, DSIZE2, DSIZE3, DSIZE4, DSIZE5 and DSIZE6, and a government owned/operated dummy variable, DGOVT. The size dummy

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[77]Courtney, Kalkbrenner, and Yie, p. 119.

[78]NTSB, pp. 22-23; Courtney, Kalkbrenner, and Yie, pp. 119-142.

[79]For more on multicollinearity and its effects, see a standard econometrics text, such as Judge, <u>et al</u>.

for gas systems with greater than 1,000,000 services, DSIZE6, is not explicitly included in the estimated incident level regression equation (in order, of course, to avoid the "dummy variable trap"[80]), but rather is implicit in its constant term. The expected relationship between size and incident levels is that the gas systems with the fewest services would have the fewest incidents and the gas systems with the most services would have the most incidents. No prior hypothesis was posited for the estimated regression coefficient of the government dummy.

The data used to create the size dummy variables was obtained from the computerized gas distribution system annual report databases maintained by the U.S. DOT. The main information used to identify government owned/operated gas systems was the name field in the U.S. DOT's annual report databases. Where a question existed after the name field had been checked, BROWN'S DIRECTORY[81] was consulted.

4.1.1.6 The Independent Variables: One-Call System Variables - The one-call system variables included in the model are PAR, the number of participants in the one-call systems to which the gas distribution system operators in the sample belong, RTIME, the request time desired by the one-call systems, INCALLS, the number of notification calls received by the systems, ADBUD, the advertising budget of the systems, CALLPOP, the number of notification calls per one-call system telephone operator, DOPTYPE, a dummy variable indicating whether the system is a contract or an in-house operation, DSCOVER1, DSCOVER2, and DSCOVER3, a set of dummies indicating the level of coverage offered by the one-call systems, and DNEWSYS, a dummy variable indicating if a one-call system is new. No prior expectations were attached to PAR, DOPTYPE, DSCOVER1, DSCOVER2, or DSCOVER3. In order that the "dummy variable trap" might be avoided, the coverage dummy variable, DSCOVER1, was left out of the estimated regression equation.

[80] Regression estimation will fail if a categorical variable is represented in a regression equation by a set of dummy variables equal in number to the number of categories present in the variable. This situation is known as the "dummy variable trap." To get around the trap, one dummy variable in the set must be excluded from the equation to be estimated.

[81] BROWN'S DIRECTORY OF NORTH AMERICAN AND INTERNATIONAL GAS COMPANIES for 1980.

It might be considered somewhat surprising that no prior hypothesis is proposed for the variable PAR. PAR, it might be thought, should be expected to vary inversely with the level of gas system incidents. After all, as membership in a one-call system expands, coordination among underground operators should improve and, since underground operators are directly or indirectly the source of much, if not most, of the excavation damage that occurs,[82] this should mean fewer incidents for participating operators, including member gas distribution systems. A countervailing process, however, may also be at work. Underground operators with a serious excavation damage problem are probably more likely to join a one-call system than are those for whom the problem is not serious (or not as serious). Consequently, one-call systems may have a disproportionate number of members with significant excavation damage problems. Systems with large memberships may be servicing areas where the problem of excavation damage is pervasive. The larger the membership, the more pervasive the problem of excavation damage may be. Of course, the more pervasive the problem, the higher the incident levels of underground operators, such as those operating gas systems, can be expected to be. Thus, PAR will be influenced by this to vary directly, not inversely, with the number of gas system incidents. Whether this effect or that resulting from improved coordination will dominate is unclear. For this reason, no prior hypothesis was specified for PAR.

The one-call variables INCALLS and ADBUD are both expected to vary inversely with gas system incident levels. INCALLS is expected to vary inversely because the more calls received by a one-call system, all other things equal, the more the public is taking advantage of and using the one-call program, and the more one-call systems are used, the more the primary benefit of the systems, reduced levels of excavation incidents, can be expected to be realized.

ADBUD is hypothesized to vary inversely with OFIS, gas system incident levels, because advertising and promotion are the primary ways in which contractors and the general public learn about and are reminded of the service offered by the one-call systems. In general, it is expected that as one-call advertising and promotion increase, so does the use of one-call systems.

[82]Courtney, Kalkbrenner, and Yie, p. 9.

The variables RTIME, CALLPOP, and NEWSYS are all expected, a priori, to vary directly with OFIS. RTIME is hypothesized to vary directly because, as the requested time between notification of impending excavation and start of work increases, it is expected that the proclivity to dig without waiting the full time also increases. This, of course, can lead to increased excavation damage. Cost considerations would undoubtedly be the primary motivation for choosing not to wait. It should be noted that request time is only partially under the control of the one-call systems. Laws in 30 states and the District of Columbia mandate the minimum length of time that must be allowed to elapse between notification of intent to dig and the beginning of excavation.[83] In some cases, the maximum allowed is mandated as well.

CALLPOP is expected to vary directly with the level of gas system incidents since the fewer calls an operator has to handle, the more quickly and expeditiously they can be handled, and the more quickly and expeditiously incoming calls are answered, the less likely it will be that callers will give up trying to contact the system and just go ahead and dig, perhaps with unfortunate consequences. Conversely, the more calls a telephone operator has to handle, the more likely it is that callers will become frustrated with the notification process and begin excavation without notifying anyone.

The estimated regression coefficient on the dummy variable NEWSYS is expected to have a positive sign because new one-call systems are not expected to be able to realize the full benefits of the one-call process during their startup period (here defined to be the first year of operation). Thus, the incident levels of participants in new systems will be expected to be higher than those of participants in established systems, all other things equal.

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[83] The states are Arizona, California, Colorado, Connecticut, Delaware, Florida, Georgia, Illinois, Maine, Maryland, Massachusetts, Michigan, Missouri, Montana, New Hampshire, New Jersey, New Mexico, New York, North Dakota, Ohio, Pennsylvania, Rhode Island, South Carolina, South Dakota, Tennessee, Utah, Virginia, Washington, Wisconsin, and Wyoming.

The participation data used for PAR (see Table 8) was obtained primarily from the "One-Call Systems Directory." Unfortunately, since a "One-Call Systems Directory" for 1982-83 was not published, the number of system participants for 1982 was unavailable from this source and had to be estimated. This was accomplished by averaging the values for 1981 and 1983 where they both were available and using the available value as the estimate for 1982 where one was missing. Missing data for 1980 and 1981 were assigned the same value as that used for 1982.

The information used to create the contract/in-house dummy, DOPTYPE (see Table 9), was also obtained from the "One-Call Systems Directory." To develop a "best guess" for the type of operation in 1982, the type of operation in the surrounding years was used. Where 1981 and 1983 were both in-house operations, the operation in 1982 was assumed to have been in-house; likewise, where the two years were contract, 1982 was assumed to have been contract. Where information for 1981 or 1983 was unavailable, information for the next available year (1980 or 1984) .was used. Where the 1981 and 1983 operations were different, the observation was dropped from the sample. Other gaps in the data were handled in a similar fashion. In a few cases, information supplied by certain of the one-call systems was used to supplement the "One-Call Systems Directory" information.

The primary source of the information used in the generation of the coverage dummies and the new system dummy, DNEWSYS, was the APWA's "One-Call Systems Directory" for various years. Supplemental information was obtained from certain of the one-call systems.

The request time data used for the model were taken from the "One-Call Systems Directory" (see Table 10 for the reported request times for the U.S. one-call systems in operation during the 1980 to 1982 period). Since no variation over time was found, the lack of 1982 data presented no problems. For the variable RTIME, all request times were converted to an hourly basis, with each "working day" being assigned 24 hours. No attempt was made to add a factor to a "working day" for weekends or holidays.

TABLE 8. SIZE OF ONE-CALL SYSTEM MEMBERSHIP

State and One-Call System	Year				
	1980	1981	1982"	1983	1984
Alabama					
Miss All	18	24	NA	26	26
Arizona					
Blue Stake (Phoenix)	10	16	NA	20	20
Blue Stake (Sierra Vista)	4	6	NA	6	6
Blue Stake (Cottonwood)	8	8	NA	4	4
Blue Stake (Prescott)	5	7	NA	6	6
Blue Stake (Tucson)	4	6	NA	10	10
Blue Stake (Flagstaff)	--	--	NA	6	6
Arkansas					
Arkansas One Call System	8	45	MA	45	45
California					
USA South	33	43	NA	85	253
USA North	44	56	NA	80	212
Colorado					
Mesa County Buried Utilities Location Service	6	6	NA	NA	NA
Blue Stake	3	3	NA	10	12
Central Locating Unit	NA	NA	NA	4	4
Fort Collins - Loveland One Call	--	--	--	--	6
Connecticut					
Call Before You Dig	241	296	NA	296	296

TABLE 8. **SIZE OF ONE-CALL SYSTEM MEMBERSHIP** (CONTINUED)

State and One-Call System	Year 1980	1981	1982*	1983	1984
Delaware					
"Miss Utility" of Delmarva	16	17	NA	20	22
Florida					
"Call Candy"	17	20	NA	25	25
Call U.N.C.L.E	23	23	NA	23	28
Underground Utilities Notification Center	12	12	NA	14	14
Construction Control Center	4	4	NA	4	5
Georgia					
Utilities Protection Center	7	9	NA	11	62
Idaho					
Palouse Empire UCC	3	3	NA	'3	7
Lewis Clark UCC	5	--	--	--	--
Utilities Underground Location Center	--	7	NA	7	13
Dig-Line	8	8	NA	8	6
Panhandle UCC	--	--	--	--	17
Illinois					
J.U.L.I.E.	45	120	NA	118	150
Digger	6	6	NA	6	6
Indiana					
Utility Locations	7	7	--	--	--
Had-Help	10	10	--	--	--
Be-A-Ware	NA	NA	--	--	--

TABLE 8. **SIZE OF ONE-CALL SYSTEM MEMBERSHIP** (CONTINUED)

State and One-Call System	Year				
	1980	1981	1982*	1983	1984
United Utilities Protection Service -- SEE OHIO					
Ruff Dig-In-Service	NA	NA	--	--	--
Kokomo Utilities UPS	NA	NA	--	--	--
Knox County One-Call	NA	NA	--	--	--
90-90 Dig In of Wayne County	NA	NA	--	--	--
Indiana Underground Plant Protection Service	--	23	56	62	84
<u>Iowa</u>					
Underground Plant Location Services	2	25	NA	20	26
<u>Kansas</u>					
Kansas One Call Center	NA	NA	NA	6	82
<u>Kentucky</u>					
BUD	12	14	NA	16	25
<u>Louisiana</u>					
DOTTIE	40	50	NA	60	80
<u>Maine</u>					
Dig-Safe -- SEE HASSACHUSETTS					
<u>Maryland</u>					
Miss Utility	23	28	NA	25	29
"Miss Utility" of Delamarva -- SEE DELAWARE					

TABLE 8. SIZE OF ONE-CALL SYSTEM MEMBERSHIP (CONTINUED)

State and One-Call System	Year 1980	1981	1982*	1983	1984
Massachusetts					
Dig-Safe	16	22	NA	22	80
Michigan					
Miss Dig	386	407	NA	440	483
Mississippi					
Mississippi One-Call Center	--	--	--	--	55
Missouri					
To Begin	6	6	NA	5	4
Nebraska					
One Call Covers All	7	8	NA	8	9
Lincoln UCC	4	4	NA	5	5
Nevada					
Can You Dig It	10	10	NA	--	--
USA North -- SEE CALIFORNIA					
New Hampshire					
Dig-Safe -- SEE MASSACHUSETTS					
New Jersey					
Garden State UPLS	22	26	NA	32	32
New Mexico					
Blue Stake (Farmington)	5	9	NA	9	9
Blue Stake (Grants)	7	6	NA	6	6
Blue Stake (Albuquerque)	6	6	NA	5	5

TABLE 8. **SIZE OF ONE-CALL SYSTEM MEMBERSHIP** (CONTINUED)

State and One-Call System	Year				
	1980	1981	1982*	1983	1984
Blue Stake (Gallup)	4	6	NA	6	6
Blue Stake (Las Cruces)	11	5	NA	--	--
Blue Stake (Santa Fe)	6	5	NA	5	5
Blue Stake (Las Vegas)	5	NA	NA	3	3
Blue Stake (Zuni)	5	5	NA	5	5
Blue Stake (Roswell)	--	5	NA	5	5
New York					
UCC of Rochester	4	6	NA	6	6
UFPO	40	47	NA	50	50
Underground ULS	5	5	NA	5	5
Underground UCC	12	15	NA	13	17
UCC (Long Island)	2	2	NA	2	2
North Carolina					
"ULOCO"	37	41	NA	41	50
Ohio					
Ohio Utilities Protection Service	30	38	NA	40	62
United UPS	4	4	4	4	4
Oklahoma					
Oklahoma One-Call System	29	45	NA	113	130
Oregon					
Utilities Underground Location Center	--	12	NA	12	14
Umatilla County UCC	NA	--	--	--	--
Wasco County UCC	NA	NA	NA	NA	12

TABLE 8. **SIZE OF ONE-CALL SYSTEM MEMBERSHIP** (CONTINUED)

State and One-Call System	Year				
	1980	1981	1982"	1983	1984
Linn Benton UCC	10	NA	NA	NA	9
Lane UCC	23	NA	NA	25	40
Douglas UCC	NA	NA	NA	NA	21
Josephine UCC	NA	NA	NA	NA	7
Rouge Basin UCC	30	NA	NA	NA	NA
Central Oregon CC	NA	23	NA	23	8
Curry CC	NA	--	--	--	--
Hoodriver UCC	NA	12	NA	12	20
East Linn CC	10	NA	NA	NA	12
City of Dallas UCC	6	6	NA	6	6
West Lane UCC	NA	--	--	--	--
Malheur UCC	--	4	NA	4	8
Klamath UCC	NA	20	NA	21	6
North Lincoln County UCC	--	--	--	--	10
South Lincoln County UCC	--	--	--	--	NA
<u>Pennsylvania</u>					
Pennsylvania One Call System	28	32	NA	36	52
<u>Rhode Island</u>					
Dig-Safe -- SEE MASSACHUSETTS					
<u>South Cardlina</u>					
Palmetto ULS	47	52	NA	53	67
<u>Tennessee</u>					
Miss Locate	1	3	NA	3	--
"Dare Dig"	--	6	NA	6	--
One Call System of Tennessee	--	29	NA	34	92

TABLE 8. **SIZE OF ONE-CALL SYSTEM MEMBERSHIP** (CONTINUED)

State and One-Call System	Year				
	1980	1981	1982*	1983	1984
Texas					
Texas One Call System	4	10	NA	10	22
One Call (Austin)	8	8	NA	9	9
Utah					
Blue Stakes Center	8	8	NA	8	10
Vermont					
Dig-Safe -- SEE MASSACHUSETTS					
Virginia					
Roanoke Valley ULS	7	7	NA	7	7
Miss Utility of Virginia	20	29	NA	29	51
Miss Utility -- SEE MARYLAND					
"Miss Utility" of Delmarva -- SEE DELAWARE					
Miss Utility of Lynchburg	4	4	NA	4	--
Washington					
Utilities ULC	53	116	NA	116	154
Grays Harbor & Pacific County UCC	15	15	NA	15	22
Cowlitz County UCC	9	9	NA	9	9
Clark County ULS	12	12	NA	12	8
Chelan-Douglas UCC	12	12	NA	12	12
Upper Yakima County UUC	15	15	NA	15	16
Klickitat-Skamania CC	18	18	NA	18	18
Walla Walla Area UCC	9	9	NA	9	9
Inland Empire UCC	15	15	NA	15	16
Palouse Empire UCC -- SEE IDAHO					

TABLE 8. **SIZE OF ONE-CALL** SYSTEM MEMBERSHIP (CONTINUED)

State and One-Call System	Year				
	1980	1981	1982*	1983	1984
Benton & Franklin Counties UCC	23	--	--	--	--
Skagit UCC	12	12	NA	--	--
Island County UCC	10	10	NA	--	--
Lower Yakima Valley UCC	NA	NA	NA	--	--
Challen-West Jefferson	10	--	--	--	--
Grant County UCC	10	--	--	--	--
Kitsap County UCC	20	--	--	--	--
West Virginia					
Miss Utility of West Virginia	11	11	NA	21	22
Cable Protection Bureau	1	--	--	--	--
Wisconsin					
Dane County One Call System	8	10	NA	12	--
Diggers Hotline	11	10	NA	12	30
Wyoming					
West Park UCC	3	3	NA	5	5
Call-In-Dig-In Safety Commission	NA	NA	NA	10	10
Freemont County UCC	11	11	NA	11	11
Central Wyoming UCC	5	5	8	8	8
Sweetwater County UCC	15	15	NA	15	15
Carbon County UCC	NA	NA	NA	6	6
Albany County UCC	15	15	NA	15	15
Southeastern Wyoming UCC	7	7	NA	7	7
Converse County UCC	--	5	NA	5	5

TABLE 8. **SIZE OF ONE-CALL SYSTEM MEMBERSHIP** (CONTINUED)

State and One-Call System	Year				
	1980	1981	1982*	1983	1984
D.C.					
Miss Utility -- SEE MARYLAND					

Sources: ONE-CALL SYSTEMS DIRECTORY, issues for 1980-81, 1981-82, 1983-84, and 1984-85; certain one-call systems.

* No ONE-CALL SYSTEMS DIRECTORY was pyblished for 1982-83.

TABLE 9. **TYPE OF OPERATION OF ONE-CALL SYSTEM**

(I = In-house, C = Contract)

State and One-Call System	Year 1980	1981	1982*	1983	1984
Alabama					
Miss All	I	I	NA	I	I
Arizona					
Blue Stake (Phoenix)	C	C	NA	C	C
Blue Stake (Sierra Vista)	C	C	NA	C	C
Blue Stake (Cottonwood)	I	C	NA	I	I
Blue Stake (Prescott)	I	C	NA	I	I
Blue Stake (Tucson)	I	C	NA	I	C
Blue Stake (Flagstaff)	--	--	NA	C	C
Arkansas					
Arkansas One Call System	C	C	NA	C	C
California					
USA South	C	C	NA	C	I
USA North	C	C	NA	C	C
Colorado					
Mesa County Buried Utilities Location Service	C	C	NA	C	C
Blue Stake	I	I	NA	I	I
Central Locating Unit	--	--	NA	I	I
Fort Collins-Loveland One Call	--	--	--	--	I
Connecticut					
Call Before You Dig	C	C	NA	C	C

TABLE 9. **TYPE OF OPERATION OF ONE-CALL SYSTEM** (CONTINUED)

State and One-Call System	Year 1980	1981	1982*	1983	1984
Delaware					
"Miss Utility" of Delmarva	I	I	NA	I	I
Florida					
"Call Candy"	I	I	NA	I	I
Call U.N.C.L.E.	I	I	NA	I	I
Underground Utilities Notification Center	I	I	NA	I	I
Call Before You Dig	I	I	NA	I	I
Georgia					
Utilities Protection Center	I	I	NA	I	I
Idaho					
Palouse Empire UCC	I	I	NA	I	I
Lewis Clark UCC	C	--	--	--	--
Utilities Underground Location Center	--	C	NA	C	C
Dig-Line	C	C	NA	C	C
Panhandle UCC	--	--	--	--	C
Illinois					
J.U.L.I.E.	C	C	NA	C	C
Digger	I	I	NA	I	I
Indiana					
Utility Locations	C	C	--	--	--
Had-Help	C	C	--	--	--
Be-A-Ware	C	C	--	--	--
United Utilities Protection Service -- SEE OHIO					
Ruff Dig-In-Service	NA	NA	--	--	--

TABLE 9. **TYPE OF OPERATION OF ONE-CALL SYSTEM** (CONTINUED)

State and One-Call System	Year 1980	1981	1982"	1983	1984
Kokomo Utilities UPS	NA	NA	--	--	--
Knox County One-Call	NA	NA	--	--	--
90-90 Dig In of Wayne County	NA	NA	--	--	--
Indiana Underground Plant Protection Service	--	C	NA	C	C
<u>Iowa</u>					
Underground Plant Location Services	C	C	NA	C	C
<u>Kansas</u>					
Kansas One Call Center	C	C	NA	I	C
<u>Kentucky</u>					
BUD	I	I	NA	I	I
<u>Louisiana</u>					
DOTTIE	I	I	NA	I	C
<u>Maine</u>					
Dig-Safe -- SEE MASSACHUSETTS					
<u>Maryland</u>					
Miss Utility	I	I	NA	C	C
"Miss Utility" of Delmarva -- SEE DELAWARE					
<u>Massachusetts</u>					
Dig-Safe	I	I'	NA	C	C
<u>Michigan</u>					
Miss Dig	I	I	NA	I	C

TABLE 9. **TYPE OF OPERATION OF ONE-CALL SYSTEM** (CONTINUED)

State and One-Call System	1980	1981	1982*	1983	1984
<u>Mississippi</u>					
Mississippi One Call Center	--	--	--	--	C
<u>Missouri</u>					
To Begin	I	I	NA	I	I
<u>Nebraska</u>					
One Call Covers All	I	I	NA	I	I
Lincoln UCC	I	I	NA	I	I
<u>Nevada</u>					
Can You Dig It	C	C	--	--	--
USA North	--	--	NA	C	C
<u>New Hampshire</u>					
Dig-Safe -- SEE MASSACHUSETTS					
<u>New Jersey</u>					
Garden State UPLS	C	C	NA	C	C
<u>New Mexico</u>					
Blue Stake (Farmington)	I	I	NA	I	I
Blue Stake (Grants)	I	I	NA	I	I
Blue Stake (Albuquerque)	I	I	NA	I	I
Blue Stake (Gallup)	I	I	NA	I	I
Blue Stake (Las Cruces)	I	I	NA	--	--
Blue Stake (Santa Fe)	I	I	NA	I	I
Blue Stake (Las Vegas)	I	I	NA	I	I
Blue Stake (Zuni)	I	I	NA	I	I
Blue Stake (Roswell)	--	I	NA	I	I

TABLE 9. **TYPE OF OPERATION OF ONE-CALL SYSTEM** (CONTINUED)

State and One-Call System	Year 1980	1981	1982*	1983	1984
New York					
UCC of Rochester	I	I	NA	I	C
UFPO	C	C	NA	C	C
Underground ULS	C	C	NA	C	C
Underground UCC	I	NA	NA	C	C
UCC (Long Island)	C	C	NA	C	C
North Carolina					
"ULOCO"	C	C	NA	C	C
Ohio					
Ohio Utilities Protection Service	I	NA	NA	C	I
United UPS	I	I	NA	I	I
Oklahoma					
Oklahoma One-Call System	C	C	NA	C	C
Oregon					
Utilities Underground Location Center	--	C	NA	C	C
Umatilla County UCC	NA	--	--	--	--
Wasco County UCC	NA	C	NA	C	C
Linn Benton UCC	C	C	NA	C	C
Lane UGC	I	C	NA	C	C
Douglas UCC	NA	C	NA	I	C
Josephine UCC	NA	C	NA	C	C
Rouge Basin UCC	C	C	NA	C	C
Central Oregon CC	NA	C	NA	C	C
Curry CC	I	--	--	--	--
Hoodriver UCC	NA	C	NA	C	C
East Linn CC	C	C	NA	C	C
City of Dallas UCC			NA	I	I

TABLE 9. TYPE OF OPERATION OF ONE-CALL SYSTEM (CONTINUED)

State and One-Call System	Year 1980	1981	1982*	1983	1984
West Lane UCC	NA	--	--	--	--
Malheur UCC	--	C	NA	C	C
Klamath UCC	NA	C	NA	I	C
North Lincoln County UCC	--	--	--	--	C
South Lincoln County UCC	--	--	--	--	C
Pennsylvania					
Pennsylvania One Call System	C	C	NA	C	C
Rhode Island					
Dig-Safe -- SEE MASSACHUSETTS					
South Carolina					
Palmetto ULS	C	C	NA	C	C
Tennessee					
Miss Locate	I	I	NA	I	--
"Dare Dig"	--	I	NA	I	--
One Call System of Tennessee	--	C	NA	C	C
Texas					
Texas One Call System	I	C	NA	C	C
One Call (Austin)	I	I	NA	I	I
Utah					
Blue Stakes Center	I	C	NA	C	C
Vermont					
Dig-Safe -- SEE MASSACHUSETTS					

TABLE 9. **TYPE OF OPERATION OF ONE-CALL SYSTEM** (CONTINUED)

State and One-Call System	1980	1981	1982*	1983	1984
Virginia					
Roanoke Valley ULS	C	C	NA	C	C
Miss Utility of Virginia	I	I	NA	I	I
Miss Utility -- SEE MARYLAND					
"Miss Utility" of Delmarva -- SEE DELAWARE					
Miss Utility of Lynchburg	C	C	NA	C	--
Washington					
Utilities ULC	C	C	NA	C	C
Grays Harbor & Pacific County UCC	NA	C	NA	C	C
Cowlitz County UCC	C	C	NA	C	C
Clark County ULS	NA	C	NA	C	C
Chelan-Douglas UCC	NA	C	NA	C	C
Upper Yakima County UUC	C	C	NA	C	C
Klickitat-Skamania CC	C	C	NA	C	C
Walla Walla Area UCC	I	I	NA	I	C
Inland Empire UCC	C	C	NA	C	C
Palouse Empire UCC -- SEE IDAHO					
Benton & Franklin Counties UCC	C	--	--	--	--
Skagit UCC	C	C	NA	--	--
Island County UCC	I	I	NA	--	--
Lower Yakima Valley UCC	NA	C	NA	--	--
Challen-West Jefferson	C	--	--	--	--
Grant County UCC	NA	--	--	--	--
Kitsap County UCC	C	--	--	--	--
West Virginia					
Miss Utility of West Virginia	C	C	NA	C	C
Cable Protection Bureau	I	--	--	--	--

TABLE 9. **TYPE OF OPERATION OF ONE-CALL SYSTEM** (CONTINUED)

State and One-Call System	1980	1981	1982*	1983	1984
Wisconsin					
Dane County One Call System	I	I	NA	I	--
Diggers Hotline	C	C	NA	C	C
Wyoming					
West Park UCC	C	C	NA	I	I
Call-In-Dig-In Safety Commission	NA	NA	NA	C	C
Freemont County UCC	C	C	NA	C	C
Central Wyoming UCC	C	C	NA	C	C
Sweetwater County UCC	C	C	NA	C	C
Carbon County UCC	C	C	NA	C	C
Albany County UCC	C	C	NA	C	C
Southeastern Wyoming UCC	C	C	NA	C	C
Converse County UCC	--	.I	NA	I	I
D.C.					
Miss Utility -- SEE MARYLAND					

Source: ONE-CALL SYSTEMS DIRECTORY, issues for 1980-81, 1981-82, 1983-84, and 1984-85.

* No ONE-CALL SYSTEMS DIRECTORY was published for 1982-83.

TABLE 10. **TIME DESIRED BETWEEN NOTIFICATION AND START OF EXCAVATION**

State and One-Call System	Request Time
Alabama	
Miss All	48 hours
Arizona (state law: 2 days)	
Blue Stake (Phoenix)	2 working days
Blue Stake (Sierra Vista)	2 working days
Blue Stake (Cottonwood)	2 working days
Blue Stake (Prescott)	2 working dsys
Blue Stake (Tucson)	2 working days
Blue Stake (Flagstaff)	2 working days
Arkansas	
Arkansas One Call System	48 hours
California (state law: 48 hours)	
USA South	2 working days
USA North	2 working days
Colorado (state law: 2 days)	
Mesa County Buried Utilities Location Service	2 working days
Blue Stake	2 working days
Central Locating Unit	2 working days
Fort Collins-Loveland One Call	2 working days
Connecticut (state law: 2 days)	
Call Before You Dig	2 working days
Delaware (state law: 2-10 days)	
"Miss Utility" of Delmarva	2 working days

TABLE 10. TIME DESIRED BETWEEN NOTIFICATION AND START OF EXCAVATION (CONTINUED)

State and One-Call System	Request Time
Florida (state law: 2 days min.)	
"Call Candy"	2 working days
Call U.N.C.L.E.	2 working days
Underground Utilities Notification Center	2 working days
Call Before You Dig	24 hours
Georgia (state law: 3-10 days)	
Utilities Protection Center	3 working days
Idaho	
Palouse Empire UCC	24 hours
Utilities Underground Location Center	2 working days
Dig-Line	48 hours
Panhandle UCC	24 hours
Illinois (state law: 48 hours)	
J.U.L.I.E.	2 working days
Digger	2 working days
Indiana	
Indiana Underground Plant Protection Service	48 hours
Iowa	
Underground Plant Location Services	2 working days
Kansas	
Kansas One Call Center	48 hours
Kentucky	
BUD	48 hours

TABLE 10. TIME DESIRED BETWEEN NOTIFICATION AND START OF EXCAVATION (CONTINUED)

State and One-Call System	Request Time
Louisiana	
DOTTIE	48 hours
Maine (state law: 48 hours)	
Dig-Safe	48 hours
Maryland (state law: 48 hours)	
Miss Utility	2 working days
"Miss Utility" of Delmarva	2 working days
Massachusetts (state law: 72 hours)	
Dig-Safe	72 hours
Michigan (state law: 2 days)	
Miss Dig	2 working days
Mississippi	
Mississippi One Call Center	48 hours
Missouri (state law: 2 days)	
To Begin	48 hours
Montana (state law: 48 hours)	
No one-call systems currently operating in state	
Nebraska	
One Call Covers All	2 working days
Lincoln UCC	24 hours
Nevada	
USA North	2 working days

TABLE 10. TIME DESIRED BETWEEN NOTIFICATION AND START OF EXCAVATION (CONTINUED)

State and One-Call System	Request Time
New Hampshire (state law: 72 hours)	
Dig-Safe	72 hours
New Jersey (state law: 3-30 days)	
Garden State UPLS	3 days
New Mexico (state law: 48 hours)	
Blue Stake (Farmington)	24 hours
Blue Stake (Grants)	2 working days
Blue Stake (Albuquerque)	2 working days
Blue Stake (Gallup)	2 working days
Blue Stake (Santa Fe)	24 hours
Blue Stake (Las Vegas)	24 hours
Blue Stake (Zuni)	24 hours
Blue Stake (Roswell)	2 working days
New York (state law: 2-10 days)	
UCC of Rochester	2 working days
UFPO	2 working days
Underground ULS	2 working days
Underground UCC	2 working days
UCC (Long Island)	2 working days
North Carolina	
"ULOCO"	48 hours
North Dakota (state law: 3 days)	
No one-call systems currently operating in state	
Ohio (state law: 48 hours)	
Ohio Utilities Protection Service	2 working days
United UPS	NA

TABLE 10. **TIME DESIRED BETWEEN NOTIFICATION AND START OF EXCAVATION** (CONTINUED)

State and One-Call System	Request Time
Oklahoma (state law: 2-10 days)	
Oklahoma One-Call System	48 hours
Oregon	
Utilities Underground Location Center	2 working days
Wasco County UCC	24 hours
Linn Benton UCC	24 hours
Lane UCC	24 hours
Douglas UCC	24 hours
Josephine UCC	24 hours
Rouge Basin UCC	24 hours
Central Oregon CC	24 hours
Hoodriver UCC	24 hours
East Linn CC	24 hours
City of Dallas UCC	24 hours
Malheur UCC	24 hours
Klamath UCC	24 hours
North Lincoln County UCC	48 hours
South Lincoln County UCC	48 hours
Pennsylvania (state law: not less than 3 days)	
Pennsylvania One Call System	3 working days
Rhode Island (state law: 48 hours)	
Dig-Safe	48 hours
South Carolina (state law: 3-10 days)	
Palmetto ULS	3 working days
South Dakota (state law: 2 days)	
No one-call systems currently operating in state	

TABLE 10. TIME DESIRED BETWEEN NOTIFICATION AND START OF EXCAVATION (CONTINUED)

State and One-Call System	Request Time
Tennessee (state law: 3-10 days)	
One Call System of Tennessee	72 hours
Texas	
Texas One Call System	2 working days
One Call (Austin)	48 hours
Utah (state law: 2 days)	
Blue Stakes Center	48 hours
Vermont	
Dig-Safe	48 hours
Virginia (state law: 48 hours)	
Roanoke Valley ULS	2 working days
Miss Utility of Virginia	2 working days
Miss Utility	48 hours
"Miss Utility" of Delmarva	2 working days
Washington (state law: 2 days)	
Utilities ULC	2 working days
Grays Harbor & Pacific County UCC	2 working days
Cowlitz County UCC	2 working days
Clark County UCC	2 working days
Chelan-Douglas UCC	24 hours
Upper Yakima County UUC	2 working days
Klickitat-Skamania CC	2 working days
Walla Walla Area UCC	2 working days
Inland Empire UCC	2 working days
Palouse Empire UCC	24 hours

TABLE 10. **TIME DESIRED BETWEEN NOTIFICATION AND START OF EXCAVATION** (CONTINUED)

State and One-Call System	Request Time
West Virginia	
Miss Utility of West Virginia	3 working days
Wisconsin (state law: 3 days)	
Diggers Hotline	72 hours
Wyoming (state law: 2 days)	
West Park UCC	48 hours
Call-In-Dig-In Safety Commission	48 hours
Freemont County UCC	48 hours
Central Wyoming UCC	48 hours
Sweetwater County UCC	48 hours
Carbon County UCC	48 hours
Albany County UCC	48 hours
Southeastern Wyoming UCC	48 hours
Converse County UCC	48 hours
D.C. (district law: 2-10 days)	
Miss Utility	2 working days

Source: ONE-CALL SYSTEMS DIRECTORY, 1984-85.

The data for the variables INCALLS and ADBUD, and the information used to create the variable CALLPOP were obtained from the various one-call systems. Where the data for these variables were not available, the average over the available observations was used. CALLPOP was created by dividing INCALLS by the number of telephone operators employed by the one-call systems. ADBUD was put into 1982 constant dollars using the Producer Price Index for all commodities.

4.1.1.7 The Independent Variables: Year Variables - Completing the variables included in the incident level model are D1980, D1981, and D1982, dummy variables for the years 1980, 1981, and 1982 (the sample period), respectively. These three dummy variables are included in the model to capture the effect that the passage of time has had on the level of outside forces incidents. To avoid the "dummy variable trap," the variable, D1980, is not included in the estimated regression equation. The expectation for these variables is that the estimated coefficients of D1981 and D1982 will be both be negative and that of D1982 will be smaller than that of D1981. The rationale for this expectation is that over time the action of one-call systems and other forms of damage prevention engaged in by the gas distribution system operators in the sample (all of which, it'should be remembered, are participants in one-call systems) should tend to generate a secular reduction in the level of excavation incidents, all other things equal.

4.1.2 The Regression Model

The regression model specified and estimated for this study was of the general form

$$OFIS(\lambda) = a + b_1X_1(\lambda) +\ldots+ b_rX_r(\lambda) + c_1D_1 +\ldots+ c_sD_s + e \qquad (1)$$

where $OFIS(\lambda)$, a transformation of the variable OFIS, is the dependent variable, $X_1(\lambda),\ldots, X_r(\lambda)$ are transformations of the non-dummy independent variables of the incident level model, $D_1,\ldots, D_s$ are the dummy variables, a, $b_1,\ldots, b_r$ and $c_1,\ldots, c_s$ are the regression coefficients, and e is error term of the regression model. The error term of the model is assumed to be normally distributed with mean zero and variance σ^2. The transformation used on the dependent and non-dummy independent variables was the Box-Cox Transformation.

This transformation takes the form

$$Z(\lambda) = \begin{cases} \dfrac{Z^{\lambda} - 1}{\lambda} & \text{if } \lambda \neq 0 \\ \ln Z & \text{if } \lambda = 0 \end{cases} \tag{2}$$

where Z is the variable transformed and λ (lambda) is the transformation coefficient.[84] Changing the value of A will, it should be noted, change the functional form of equation (1). When λ equals zero, for example, equation (1) will be log-linear; when it equals one, equation (1) will be linear. The value λ takes can be specified prior to estimation, if theory indicates what is appropriate, or determined during the estimation process.

The Box-Cox Transformation was used in the statistical modelling of incident levels for two reasons. First, preliminary estimation work indicated that the residuals of a standard linear regression model of incident levels estimated using ordinary least squares would be non-normal. Since the normality of the residuals is one of the basic underlying assumptions of classical linear regression, an alternative approach needed to be found. The use of the Box-Cox Transformation is one way in which the distribution of the residuals may be brought closer to normality.[85] The second reason for using the Box-Cox Transformation is that its use allows a model with a more flexible, less restrictive functional form to be estimated.

To obtain maximum likelihood estimates of the coefficients of the regression model, the following procedure was used. First, untransformed variables were transformed using a value for lambda chosen from a range of reasonable values. Then, a regression equation that includes the transformed variables was estimated with ordinary least squares and the log-likelihood function of the estimated equation was evaluated.[86] This process was

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[84] For more on the Box-Cox Transformation, see Box and Cox, or Zarembka, 1968.

[85] Zarembka, 1974, p. 87.

[86] For the log-likelihood function to be calculated, it is neoessary that OFIS be strictly greater than zero (since ln(OFIS) must be evaluated for every observation in the sample). Consequently, where OFIS equalled zero in the sample, an arbitrarily small number, .00001, was added to it.

repeated with new values of lambda until a global maximum for the log-likelihood function was found.[87] The estimated coefficients of the equation where the log-likelihood function is maximized are the maximum likelihood estimates of the coefficients of the regression model.

4.2 ESTIMATION RESULTS

The estimated coefficients of the incident level regression model, their t-ratios, and selected summary regression statistics are presented in Table 11. Overall, the model appears to have performed well. The R^2 for the regression model was found to be .723, indicating a fairly good fit. The values of the adjusted R^2 (=.705) and the Barten's R^2 (=.706) indicate that the fit can still be considered to be good even after the degrees of freedom of the model and much of the statistical bias inherent in the R^2 and the adjusted R^2 are taken into account.[88] The F-statistic for the model, 38.522, is statistically significant at the 90 percent level, indicating that the joint hypothesis that all of the coefficients in the regression equation are equal to zero must be rejected.

The value of lambda at which the log-likelihood function achieved a maximum was .19. Using likelihood ratio tests,[89] this value was found to be significantly different from both zero (log-linear functional form)[90] and one (linear functional form) at the 90 percent level of confidence. Thus, the hypothesis that the appropriate functional form of the model is either log-linear or linear can be rejected.

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[87] The computer program used for this procedure was written in the matrix-oriented programming language, GAUSS™. The estimation was carried out on an IBM PC-AT.

[88] For more on Barten's R^2, see Barten.

[89] Zarembka, 1974, p. 86.

[90] To evaluate the log-likelihood function for $\lambda=0$ for use in the likelihood ratio test, all untransformed variables must be strictly positive (because a natural logarithmic transformation will be used). This requirement necessitated the addition of an arbitrarily small number, .00001, to ADBUD in the eight observations in the sample where this variable was equal to zero. No other independent variables required any modification. Prior modification of the untransformed dependent variable made modification for the calculation of the log-likelihood function for $\lambda=0$ unnecessary (see Footnote 86).

TABLE 11. ONE-CALL ESTIMATION RESULTS

(t-Statistics Given in Parenthesis)

Note: VARIABLE(λ) = (VARIABLE' - 1)/λ
λ = LAMBDA

Variable Category and Independent Variable	Dependent Variable: OFIS(λ)
CONSTANT	-1.309 (-.181)
Exposure Variables	
CONSTN(λ)	.642[a] (1.786)
PIPE(λ)	.595[a] (7.629)
POP(λ)	-.129 (-1.119)
State Damage Prevention Law Variables	
DLAW1	-1.899[a] (-2.131)
DLAW2	.502 (.564)
DLAW3	.946 (1.329)
Gas Company Variables	
DSIZE1	-1.488 (-.446)
DSIZE2	-.693 (-.262)
DSIZE3	-.974 (-.411)

TABLE 11. **ONE-CALL ESTIMATION RESULTS** (CONTINUED)

Variable Category and Independent Variable	Dependent Variable: OFIS(λ)
<u>Gas Company Variables **(Cont.)**</u>	
DSIZE4	.473 (.234)
DSIZE5	.534 (.333)
DGOVT	-.171 (-.272)
<u>One-Call System Variables</u>	
PAR(λ)	.421[b] (2.242)
RTIME(λ)	.305 (.309)
INCALLS(λ)	-.074[a] (-1.464)
ADBUD(λ)	-.110[a] (-2.606)
CALLPOP(λ)	.102 (.846)
DOPTYPE	,263 (.472)
DSCOVER2	-2.564[b] (-3.616)
DSCOVER3	2.043[b] (2.071)
DNEWSYS	-1.031 (-.768)
<u>Year Variables</u>	
D1981	-1.490[a] (-2.860)

TABLE 11. ONE-CALL ESTIMATION RESULTS (CONTINUED)

Variable Category and Independent Variable	Dependent Variable: **OFIS(λ)**
Year Variables (Cont.)	
D1982	-.342 (-.612)
Transformation Coefficient	
LAMBDA	.19[c]
Summary Statistics	
F-Statistic	38.522[d]
R^2	.723
Adjusted R^2	.705
Barten's R^2	.706
Number of Observations	363
Degrees of Freedom	339

[a]Significantly different from zero at the 90% level of confidence (using one-tailed t-test).

[b]Significantly different from zero at the 90% level of confidence (using two-tailed t-test).

[c]Significantly different from zero (log-log model specification) and from one (linear model specification) at 90% level of confidence (using likelihood ratio test).

[d]Significant at the 90% level of confidence (using F-test).

4.2.1 The Coefficients of the Model

As can be seen in Table 11, nine of the variable coefficients proved to be significant at the 90 percent level of confidence. The others, including the intercept term, proved not to be statistically significant.

4.2.1.1 The Exposure Coefficients -- The coefficients of the exposure variables, CONSTN(λ) and PIPE(λ), were found to be statistically significant at the 90 percent confidence level using a one-tail t-test. The signs of both coefficients, as expected, were positive, indicating that, as construction or gas system pipeline mileage increases, the number of outside forces incidents experienced by the gas distribution system members of one-call systems increases. The coefficient of the exposure variable, POP(λ), did not prove to be statistically different from zero, implying that population by itself does not impact gas distribution system outside forces incident levels.

4.2.1.2 The State Damage Prevention Law Coefficients -- The coefficient of only one state law variable, DLAW1, proved to be significant at the 90 percent level of confidence. The coefficients on DLAW2 and DLAW3, the other two state law dummy variables in the model, were not found to be significant. The sign on the DLAW1 coefficient, as expected, was negative, confirming the prior hypothesis about the impact of the variable, DLAWl, on the level of gas distribution system outside forces incidents.

The statistical significance and negative sign of the estimated coefficient of the state law dummy, DLAW1, would seem to indicate that the promulgation of state'damage prevention laws might be one way to bring about a decrease in the level of excavation damage occurring to gas distribution systems participating in one-call systems, and probably in that occurring to other system participants and many, if not most, non-participants, as well. This, of course would only lead to an improvement of the situation in states that do not already have damage prevention laws. As of 1985, there were eighteen states without underground damage prevention laws or regulations.[91]

[91] These states are Alabama, Alaska, Arizona, Arkansas, Hawaii, Idaho, Indiana, Iowa, Kansas, Kentucky, Minnesota, Mississippi, Nebraska, Nevada, Oregon, Texas, Vermont, and West Virginia. Three of these (Alaska, Hawaii, and Minnesota) do not have any one-call systems in operation within the state.

The total decrease in outside forces incidents that might result if all of these states enacted damage prevention laws could be fairly substantial.

The lack of statistical significance of the coefficients of DLAW2 and DLAW3 is of considerable import since it indicates that these variables have little impact on the level of outside forces incidents occurring to gas distribution systems participating in one-call systems. This finding would seem to imply that there is low incremental value to state legal requirements that underground operators must respond to all excavation notices or must participate in one-call systems. It should be noted that mandatory one-call participation may be a good way to get one-call coverage for areas or firms whose facilities are not presently covered by a system.

4.2.1.3 The Gas Company Coefficients -- As can be seen in Table 11, none of the coefficients of the gas company variables in the model proved to be statistically significant at the 90 percent level of confidence. This means that gas system size does not appear to impact the level of gas system incidents in a way not already accounted for by the exposure variables in the model. It also means that government ownership/operation of a gas system will, all other things equal, have neither an adverse nor a propitious effect on incident levels.

4.2.1.4 The One-Call System Coefficients -- The estimated coefficients of five of the one-call system variables included in the model proved to be statistically significant at the 90 percent level of confidence. These were the coefficients of the variables, PAR(λ), INCALLS(λ), ADBUD(λ), DSCOVER2, and DSCOVER3. The estimated coefficients of RTIME(λ), CALLPOP(λ), DOPTYPE, and DNEWSYS, the other four one-call variables in the model, were not found to be statistically significant. The signs on the regression coefficients of INCALLS(λ) and ADBUD(λ) were negative, as expected. There were no prior hypotheses, it should be recalled, for the coefficients of PAR(λ), DSCOVER2, and DSCOVER3, the other three one-call variables with statistically significant coefficients.

The sign of the estimated coefficient of PAR(λ) proved to be positive. This seems to indicate that, of the two processes influencing the relationship between the number of one-call participants and gas distribution system incident levels, which might be referred to as the "improved coordination" and the "pervasive problem" processes, the "pervasive problem" process dominates, at least in the sample under consideration in this study.

Given the estimation results for the coefficients of the one-call variables, ADBUD(λ), DSCOVER2, and DSCOVER3, it appears that one-call systems can use their level of advertising and promotion, and type of coverage to actively improve the outside forces damage situation within their service regions.

The negative sign on the coefficient of the variable ADBUD(λ) means, of course, that increasing the amount spent on advertising and promotion by one-call systems can be expected to decrease the level of incidents experienced by their member gas distribution systems, and probably by their other member operators, as well. Thus, by expanding their advertising and promotion (and thereby getting their message about their service and its benefits to a wider audience) one-call systems can generate an improved safety environment for their members. Of course, at some point the incremental decrease in incidents will cease to justify additional advertising expenditures. Where this point is reached will depend on a number of conditions and will probably vary from one-call system to one-call system.

The signs on the coefficient estimates obtained for DSCOVER2 and DSCOVER3 indicate that, all other things equal, the gas distribution system operators with the best performance (i.e., the lowest levels of outside forces incidents) belong to non-statewide one-call systems operating in states with complete one-call coverage. The next best are those belonging to systems providing statewide coverage. The worst are those participating in systems operating in states with incomplete one-call coverage. The reason that these gas system operators have the worst performance may result from operating inefficiencies inherent in the operation of the often quite small one-call systems in which they participate. In comparing the performance of gas distribution system operators participating in non-statewide one-call systems operating in states where all areas have one-call service with that of operators participating in statewide one-call systems, the better performance of the former can probably be attributed, at least in part, to the fact that the non-statewide systems will generally be providing service more attuned to iocal conditions and needs (because they are, after all, more local in nature) than statewide systems can be expected to provide. The non-statewide systems operating in states with complete one-call coverage seem to be larger and more organized than the systems in states with incomplete coverage, and as a consequence, they are probably able to avoid most of the operating inefficiencies the smaller, less organized systems experience.

The trend in recent years has been the formation of statewide one-call systems. It is expected that this trend will continue in the future.[92] While non-statewide systems in states with statewide coverage, it appears, have lower incident levels, it is possible that structures could be set up and procedures established that would give statewide systems more local input and thereby bring them closer to the situation existing in non-statewide systems operating in states that have no areas not serviced by a one-call system. In particular, systems might set up local underground coordinating committees throughout their service regions (or formally incorporate those that already exist into the one-call process) to better enable them to keep an eye on local conditions and needs, and to facilitate contact and coordination between and among local excavation contractors, underground operators, and the system. The result should be improved participant performance.

The estimated coefficients of the variables RTIME(λ), CALLPOP(λ), and DOPTYPE, as mentioned before, were not found to be statistically different from zero. This means, of course, that the three variables, which are, in the main, under the control of the one-call systems, do not impact the level of gas distribution system outside forces incidents. This finding is quite significant, since it implies that one-call systems have flexibility in their choice of request time (constrained, of course, by the requirments of state law), telephone operator staff size, and type of system operation (in-house or contract).

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[92] General Discussion, Session #9, "Imaginuity: Solving Your One-Call Problems," 9th Annual One-Call Symposium, Chicago, 1984.

4.2.1.5 The Year Coefficients -- Of the two year variables included in the model, only one, D1981, was found to have a statistically significant coefficient; the other, D1982, was not. The negative sign on the estimated coefficient of D1981 was in accord with prior expectations. However, since the coefficient on D1982 was not statistically different from zero, the hypothesized downward secular trend in gas system outside forces incidents was not demonstrated by the model.

4.2.2 Elasticity Estimates

Table 12 contains estimated gas distribution system incident elasticities for the non-dummy variables in the incident level model. To facilitate interpretation, these elasticities have been calculated in terms of the untransformed form of the variables. An elasticity is defined to be the percentage change in the dependent variable that could be expected to result from a one percent change in an explanatory variable. From a policy point of view, given the impetus for this study, undoubtedly the most important elasticity reported in Table 12 is that of ADBUD. The elasticity estimate, -.23, indicates that one-call systems can expect a decrease in gas distribution system incidents of a little over .2 percent for every one percent increase (in real terms) in advertising and promotional expenditures. Conversely, a one percent decrease in advertising can be expected to result in around a .2 percent increase in incidents. Thus, system operators should consider very carefully when contemplating a decrease in their advertising' budget.

TABLE 12. **ESTIMATED GAS DISTRIBUTION INCIDENT ELASTICITIES**
(Evaluated at Variable Means)

Variable Category and Independent Variable	Dependent Variable: **OFIS**
Exposure Variables	
CONSTN	0.29
PIPE	0.96
POP	0.00
One-Call Svstem Variables	
PAR	0.33
RTIME	0.00
INCALLS	-0.23
ADBUD	-0.23
CALLPOP	0.00

Note: (1) An elasticity is the percentage change in the dependent variable resulting from a one percent change in an independent variable.

(2) The elasticities presented in this table have been evaluated for the untransformed variables.

(3) Elasticities are presented in this table only for the non-dummy variables in the estimated incident level equation. Dummy variable elasticities are not reported because they have no meaning.

5. SUMMARY AND CONCLUSIONS

This report has examined both the nature of outside forces damage, the most important cause of U.S. gas pipeline incidents, and the efforts that have been made by government and industry to control it. To help develop a fuller understanding of outside forces damage and the impact of damage programs, such as one-call systems, on it, a statistical model of the level of outside forces incidents faced by gas distribution system operators participating in one-call systems was specified and statistically estimated.

The statistical model developed for this study was estimated using gas system and one-call data for the years 1980 through 1982. The sample used in the estimation consisted of 363 observations on gas distribution system operators operating in 26 states and participating in 41 one-call systems and system "overlaps." The model used in the estimation included variables representing all of the major factors that influence outside forces incidents. In addition to regression coefficients, elasticity estimates were developed in the analysis for the non-dummy variables of the model. These estimates indicate the percentage change in the dependent variable of the regression model (or a transformation thereof) that would be expected to result from a one percent change in an independent variable.

A number of findings came out of the statistical modelling of the incident levels of gas distribution system operators belonging to one-call systems. Principal among these findings are (1) the level of gas distribution system incidents is affected by the level of construction and by gas system pipeline mileage, as would be expected, (2) the presence of a state damage prevention law affects the level of incidents, but state requirements that operators respond to all excavation notices and participate in one-call systems do not, (3) government owned/operated gas distribution systems do not differ in performance from non-government systems, (4) neither in-house one-call operations nor contract one-call operations are superior to the other in controlling incidents, (5) the level of advertising engaged in by a one-call system affects the level of its gas system participants* outside forces incidents (a one percent increase in advertising expenditures can be expected to yield around a .2 percent decrease in gas system incident levels), (6) neither a system operator's request time nor its average number of incoming calls per telephone operator affect the level of gas distribution system incidents, and (7) the type of coverage provided by a one-call system affects the level of gas system incidents.