the news media. In potentially fast or fast-developing incidents, the news media was generally augmented by telephone, public address, and door knocking (16,27). Each potential impact area should be studied to determine an optimum warning system. New innovations such as computer telephoning, planes with loudspeakers, etc., should be explored (22,33).

A correlation was made between population density and the time required to evacuate the affected area (figure 1) from information received on questionnaires. The data are for private vehicles which were the predominant mode for evacuation (more than 99 percent). Evacuations were selected which involved urban, suburban, or rural areas only, and not mixtures. Population density ranged from approximately 15 persons per square mile to 20,000 persons per square mile.

The evacuation time ranged from approximately two to eighteen hours. Regression analysis up to a fourth degree polynomial provided the best curve fit and is indicated by the line through the data points (34). The line is described by the following equation: log (hours) = 1.30571 - 0.21243 log (persons/square miles) with a standard deviation of 1.5 hours and a correlation coefficient of -0.71.

The data indicates that more time is required for evacuation as population density decreases. Several reasons may be postulated for this:

1. The evacuation times reported in the questionnaire include the warning times as well as the time required to move the population out of the affected area. Warning times may lengthen as the population density decreases because of increasing distances between persons and more individual contacts may have to be made.

2. More time is required to prepare farms for a "shut down" than for residential dwellings.

3. Road networks generally decrease as the population density decreases; therefore, more time may be required for evacuation because of limited choice and direction of roads.

Some evacuation investigated occurred in high density urban and suburban areas approaching the population density of New York City and Los Angeles which have 26,000 and 6,000 persons per square mile, respectively (8). Two such cities,

NUCLEAR REGULATORY COMMISSION

Docket No. 50-352/353 — Form Env. No. Ap.14-2

In the matter of Philadelphia Electric ✓

Staff ___

Applicant ✓

Intervenor ___

Cred'd (RT) ___ — Rejected ___

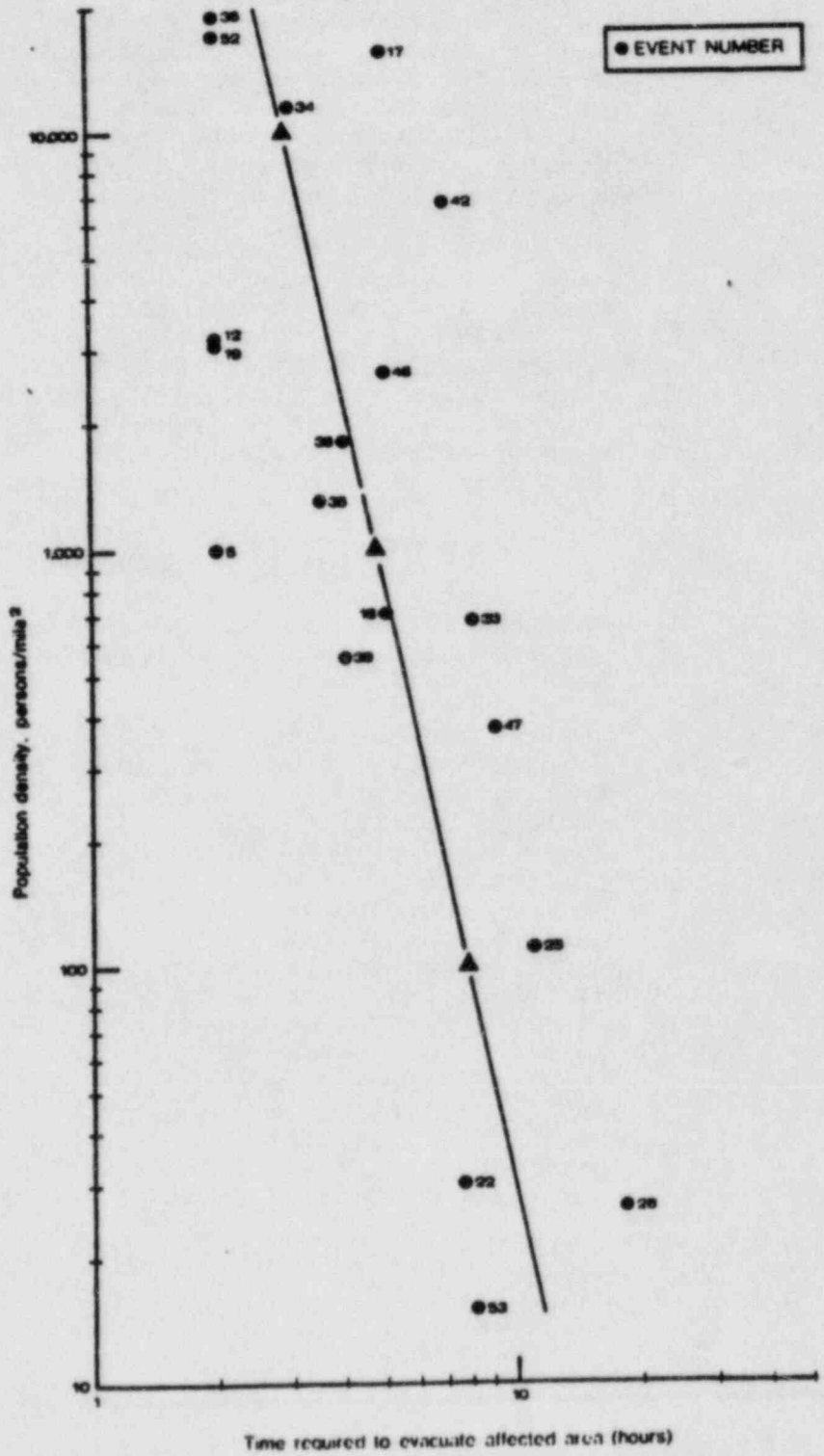
Contractor ___ — Date 5/22/81

Other ___ — Action ___

Reporter Ann Riley

Figure 1

Population Density vs. Evacuation Time



Baton Rouge, Louisiana (150,000 persons) and Wilkes-Barre, Pennsylvania (75,000 persons) were almost totally evacuated in two and five hours, respectively. The metropolitan business district of downtown Portland, Oregon, with a population of 101,000 persons and a population density of 25,200 persons per square mile, was evacuated in less than one hour during a Civil Defense test exercise (35). Although no correlation could be determined relating the total number of persons evacuated with evacuation time, two theoretical evacuation studies for large populations (more than 1,000,000 persons) show that such evacuations are possible within a reasonable time span. One study concluded that 4,300,000 persons could be evacuated from the Los Angeles Basin area in less than five hours (36). The other study, concerning the evacuation of approximatelty 2,200,000 children from the New York City metropolitan area, indicated that the evacuation could be accomplished in one to three days without disturbing normal weekday metropolitan activities (37). If the evacuation occurred on a Sunday, it could be accomplished during daylight hours.

A statistical comparison was made on the events used in figure 1 to determine if the use of a plan for an evacuation reduced the time required to evacuate the affected area. Based on the information collected, no significant difference between the evacuations utilizing a plan and those in which no plan was used could be determined.

An approximation can be made of the time required to evacuate affected areas based on the load capacity of roads. Several studies have been made on evacuation times related to road capacities (20,33,36,38). Estimates indicated that 1,000 vehicles could be moved per lane per hour (36). In observations during evacuations, 1,100 to 4,080 cars per lane per hour were observed (20,35,38). The average of actual observations was approximately 2,600 cars per lane per hour. The average vehicle occupancy observed during a large evacuation was four persons (35). Assuming 2,600 cars per lane per hour with an occupancy of four persons each, about 10,000 persons can be evacuated per lane per hour. Vehicle speeds observed ranged from 25 to 45 mph (with an average of 35 mph) during the evacuation (20,35,38). In addition to the time calculated, based on flow rate and vehicle occupancy, more time must be allowed for the warning period and for the average time required to drive out of the impact area.

Based upon Dr. Dynes' response to the specific question of behavior to radiation versus other threats, corroborated by the research (40) that reveals the true behavior of people during a disaster as opposed to the panic conception, there is no reason to believe or assume that the risk of injury or death should be any higher due to an evacuation than the normal accident or injury rate.

" . . . one fact is borne out by various data of past disasters: the freedom to escape from threat of death or injury has a calming effect on the population." (37)

Motivation to evacuate

In many cases, even when presented with a grave threat, people refuse to evacuate (16,23,28,40). Many reasons have been given both by persons who have not evacuated (17,23), and persons conducting the evacuation as to this reluctance to leave. To some degree, it is the individual's impressions and interpretation of the seriousness of the situation based on the official or unofficial information he/she receives. An individual evaluation is made and a positive or negative action elicited. It cannot be taken for granted that an official order to evacuate will be followed, even if it is a mandatory rather than a voluntary order. Results of this study indicate that approximately six percent of the total population refused to evacuate. Other reports indicate this figure can run higher than 50 percent (23).

There is no reason to believe that because the disaster agent is radiation rather than some other agent, that is, in itself, will provide sufficient motivation to leave. Rather, the opposite viewpoint should be taken--people will be hesitant to leave. Cognizance should be given in the planning stage to this problem and appropriate thought given to its remedy.

Warning systems and communication systems between evacuee-evacuator, evacuator-evacuator, and evacuator-news media-population play a significant role in the emergency and/or evacuation process (17,42,43). It is not only important that pretested, workable systems be available, but that an understanding of peoples' response and behavior to warning systems be recognized and be advantageously used.

Emergency plans

There have been many documents published on emergency and disaster planning (44-48), some of which are listed in the bibliography. It was not the intent of this report to go into

APPENDIX B

SUMMARY OF EVACUATION QUESTIONNAIRES

EVENT NUMBER	LOCATION, DATE AND CAUSE FOR EVACUATION	TYPE OF AREA EVACUATED	AREA EVACUATED (SQ. MILES)	NUMBER OF PERSONS EVACUATED	DISTANCE (MILES) EVACUATED	EVACUATION TIME (HOURS)	DEATHS	INJURIES	TIME PERSONS IN EVACUATION STATUS (HOURS,	POPULATION DENSITY #/SQ. MILE	PERSON-MILES x 10^3	TIME BETWEEN EVACUATION AND ONSET OF INCIDENT (HOURS)	ROAD AND CONDITIONS *	WEATHER	TIME OF DAY	EVACUATION PLANS†	REMARKS
1	Clatsop Co., OR; 1/11/72; Flood	Rural Farming	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	Wet, N.D.	Rain	Day Night	P	Some moved to higher ground to neighbors
2	Clatsop Co., OR; 1/8/71; Flood	Surburban	0.02	10 of 300	N.D.	N.D.	0	0	N.D.	15,000	N.D.	N.D.	Wet U5R	Rain	Day Night	PU	Private vehicles
3	Clatsop Co., OR; 12/22/64; Flood	Rural Farming	N.D.	2 of 120	N.D.	0.5	0	0	16	N.D.	N.D.	N.D.	Wet N.D.	Rain	Day	PU	Private vehicles
4a	Okanogan Co., WA; 5/72; Flood	Rural Farming; Rural Residential, Urban	5.0	240	1.0	1.25	0	0	240	N.D.	240	N.D.	Wet R	Rain	Day Night	PU	Mixed areas; Private vehicles
4b	Okanogan Co., WA, 5/72; Flood	"	5.0	450	1.0	1.25	0	0	240	N.D.	450	N.D.	Wet R	Rain	Day Night	PU	Supplied vehicles
4c	Okanogan Co., WA; 5/72; Flood	"	N.D.	48	0.1	N.D.	0	0	240	N.D.	4.8	N.D.	N.A.	Rain	Day Night	PU	Boat evacuation
5	Douglas Co., WA; 9/6/72; Flash Flood	Suburban	2.0	50 of 3000	1.0	2.0	0	0	24	1000	50	0	Wet S	Rain	Night	N.D.	Private vehicles

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6a	Ferndale, WA; 1/8/71; Flood	Rural Farming; Fishing	30	60	10	4.0	0	1	288	6.7	600	72	Wet R	Rain	Day Dusk	PU	Private vehicles; Indian Reservation; Heart attack
6b	Ferndale, WA; 1/8/71; Flood	"	30	140	8.0	4.0	0	0	288	6.7	1.12k	72	Wet R	Rain	Day Dusk	PU	Supplied vehicles
6c	Ferndale, WA; 1/8/71; Flood	"	30	25	1.0	4.0	0	0	288	6.7	25	72	N.A.	Rain	Day Dusk	PU	Boat evacuation
7	Chehalis Indian Reservation, WA; 12/22/72; Flood	Rural Farming	8.0	38	25	[illegible]	0	0	84	N.D.	950	3	Wet R	Rain	Night	PU	Private vehicles
8	Shoreline WA; 3/64, Tsunami	Recreation	35	900	20	1.0	0	0	6.0	69	18,000	1.25	Dry R	Clear	Night	PU	Private vehicles; Coast line evacuated; 1500 transients; Vacationers present
9	Port Angeles, WA; 6/16/61; Flood	Suburban	1.0	100	0.5	2	0	0	N.D.	N.D.	50	40	Wet U	Rain	Night	P	Private vehicles
10	Port Angeles, WA; 10/1/71; Fire	Urban	0.01	50	1.0	N.D.	0	0	N.D.	N.D.	50	0	Dry U	Clear	Night	NP	Private vehicles
11	Prairie City, OR; 6/69; Flash Flood	Rural Residential	0.5	30	1.0	N.D.	0	0	720	60	N.D.	0	Wet R	Rain	Night	NP	Drive-out; Walk-out; Boat; No Breakdown
12	Downington, PA, 2/5/73; Transportation	Suburban	0.25	700 of 800	1.0	2.0	0	0	6.5	1200	700	1.0	Dry S	Cloudy	Night	PU	Private vehicles

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13	Crystal City, CA; 3/28/64; Tsunami	Urban	0.5	N.D.	0.5	N.D.	0	0	72	N.D.	N.D.	0.75	Dry U	Clear	Night	PU	Private vehicles; Jail & Hospital evacuated to higher floors
14	Cannon Beach and Seaside, OR; 3/28/64; Tidal Wave	Urban	3.5	3,100 of 3,700	2.0	1.5	0	1	5.0	1,037	6,200	0	Wet USR	Cloudy	Night	N.D.	Mostly walk-out; Part of town not alerted due to short warning
15	Logansport, LA; 5/16/69; Transportation	Suburban; Urban	13	1,800	2.0	N.D.	0	0	24	138	3,600	0.3	Dry S	Clear	Day	NP	Private vehicles
16	Creve Coeur, IL; 8/1/61; Transportation	Rural Residential; Suburban; Urban	15	7,500	12	1.0	0	0	5.5	500	90,000	0	Dry S	Fog	Night	PU	Private vehicles
17	Wilkes Barre, PA; 6/23/72; Flood	Urban	5.0	75,000 of 78,000	1.0	5.0	0	0	120	15,600	77,000	5	Wet U	Rain	Dawn Day	PU	Hospitals and Jail evacuated
18	Chadbourne, NC; 1/13/68; Transportation	Suburban	0.5	350	1.0	5.0	0	0	48	700	350	0	Dry S	Cloudy	Dusk Night	NP	Private vehicles
19	Port Aransas, TX; 9/61; Hurricane	Urban	1.3	2,800 of 4,000	50	2.0	0	0	N.D.	3,100	140,000	48	Dry R	Cloudy	Day	PU	Private vehicles
20	Robestown, TX; 7/3/70, Hurricane	Urban	0.08	450	3.5	1.5	0	0	168	5,600	1,575	0	Wet R	Rain	Dusk	PU	Supplied vehicles
21	Payson, AZ; 9/70; Flash Flood	Rural Residential; Recreation	20	160	1.0	12	0	0	N.D.	8	160	0	Wet R	Rain	Day	PU	Private vehicles

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22	Chambers Co., TX; 9/3/71; Hurricane	Rural Farming	336	10,000 of 10,200	50	[illegible]	0	0	72	30	500,000	48	Wet UR	Rain Gale	Day Night	PU	Private vehicles
23	Greely, CO; 4/12/73, Dam Break	Rural Residential	3.0	1,000	1.0	3.5	0	0	24	330	1,000	7.5	Dry S	Clear	Day	PU	Private vehicles
24	Portland, OR; 12/7/55; CD Test Evacuation	Urban	4	101,000	1.5	0.5	0	0	N.D.	25,000	151,500	N.A.	Wet U	Rain	Day	PU	Private vehicles
25	Isleton, CA; 6/21/72; Flood	Suburban	11	1,200	40	11	0	0	2,160	109	48,000	14	Dry EU	Clear	Day	NP	Private vehicles
26	Humbolt Co., CA; 12/22/64; Flood	Rural Residential	450	183	25	N.D.	7	0	N.D.	N.D.	4,600	N.D.	N.A	Rain	Day	P	Helicopter evacuation
27a	Glenn Co., CA; 2/73; Flood	Rural Farming	20	30	6	4.0	0	0	N.D.	N.D.	180	N.D.	N.A.	Rain	Day Night Dawn Dusk	N.D.	Helicopter evacuation
27b	Glenn Co., CA; 2/73; Flood	Rural Farming	20	20	6	N.D.	0	0	N.D.	N.D.	120	N.D.	Wet R	Rain	"	N.D.	Supplied vehicles
28	King Co., WA; 3/59; Flood	Rural Farming	20	300 of 512	10	18	0	0	192	26	5,000	72	Wet R	Rain	Day Dusk Night	PU	Private vehicles
29	Kelso, WA; 1/18/72; Flood	Rural Residential	10	70	5	48	0	0	2,160	7	350	24	Wet R	Rain	Night	PU	Private & Supplied vehicles; No breakdown on use
30a	Port Arthur, TX; 9/3/61; Hurricane	Hospital	N.D.	80	20	4	0	0	72	N.D.	1,600	48	Dry R	Clear	Day	PU	Hospital evacuation; ambulatory by private vehicles

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30b	Port Arthur, TX; 9/3/61; Hurricane	Hospital	N.D.	20	20	4	0	0	72	N.D.	400	48	Dry R	Clear	Day	PU	Hospital;non-ambulatory; ambulance evacuation
31	Jefferson Co., TX; 9/3/61; Hurricane	Suburban; Urban; Industrial	945	108,600 of 113,600	80	7.5	0	0	72	120	8,688,000	48	Dry S	Clear	Day	PU	Private vehicles; Predominantly large scale urban evacuation
32	Hagerstown, MD; 2/27/68; Transportation	Suburban	0.06	2,500	N.D.	N.D.	0	0	12	42,000	N.D.	0	Dry S	Clear	Night	NP	Private vehicles
33	Wetonka, OK; 4/4/69; Transportation	Rural Residential	3	2,000	25	8	0	0	27	667	50,000	0	Dry S	Cloudy	Day	PU	Private vehicles
34	Louisville, KY; 3/19/72; Transportation	Urban	0.35	4,000	1	3	0	0	24	11,400	4,000	N.D.	Wet U	Rain	Day	PU	Private vehicles; Chlorine barge; No chlorine release
35	Urbana, OH; 8/13/65; Transportation	Suburban	3.1	4,000	0.75	3.5	0	0	24	1,300	3,000	0	Dry S	Clear	Dawn	N.D.	Private vehicles
36	Baton Rouge, LA; 8/65; Transportation	Urban	8	150,000	30	2.0	0	0	5.0	19,000	4,500,000	N.D.	Dry U EU.	Clear	Day	PU	Private vehicles; Chlorine barge; No chlorine release
37	St. Marys Parish, LA; 9/64; Hurricane	Rural Residential; Urban	1,036	40,500 of 45,000	150	8	0	0	72	43	6,075,000	12	N.D. U	N.D.	N.D.	PU	Private vehicles
38	Morgan City, LA; 1/19/73; Transportation	Urban	1.8	3,000 of 3,300	2	4	0	0	60	1,800	4,000	6	Ice U	Snow	Day	PU	Private vehicles Chlorine barge; No chlorine release
39	Texarkana, TX; 8/27/67 Transportation	Suburban	9.0	5,000	3	4	0	0	4.0	550	15,000	1	Dry U	Clear	Night	NP	Private vehicles

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40	Grand Valley, CO; 9/10/59; Nuclear Detonation (Plowshare)	Rural Farming; Industrial	20	300 of 307	5	1.0	0	0	7.0	15	1,500	4	Dry R	Cloudy	Day	PU	Private vehicle; Heavily planned and supervised
41	Grand Isle, LA, 9/3/61; Hurricane	Rural Residential; Industrial	1.8	2,700 of 2,300	70	3.5	0	0	N.D.	1,300	134,000	82	Wet R	Rain	Day Dusk	NP	Private vehicles
42	Los Angeles, CA; 2/9/71; Earthquake	Suburban	12	80,000	N.D.	7	0	0	240	6,700	N.D.	3	Dry U	Clear	Day	N.D.	Private vehicles
43	Seabrook IS, SC, 1/19/59; Hurricane	Suburban	4.5	208	0.6	4	0	0	12	46	125	10	N.A.	Rain	Day Dusk Night	PU	Boat evacuation
44	Glendora, MS; 9/11/69; Transportation	Rural Farming; Rural Residential; Suburban; Urban	1,200	35,000	20	4	0	0	9.0	29	700,000	5	Dry S	Cloudy	Night	P	Private vehicles
45a	Anderson, SC; 7/9/68; Flash Flood	Suburban	0.09	60	0.06	2	0	0	24	1,700	3.6	0	N.A.	Rain	Night	NP	Boat evacuation
45b	Anderson, SC; 7/9/58; Flash Flood	Suburban	0.09	150	0.75	2	0	0	24	1,700	200	0	Wet U	Rain	Night	NP	Supplied vehicles
46a	TX; 9/3/61; Hurricane	All Types	N.D.	501,000	N.D.	N.D.	0	0	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	Persons from events # 22 & 31 subtracted from total

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46b	Plaquemines Parish, LA; 9/3/61; Hurricane	All types	N.D.	23,000	N.D.	N.D.	9	0	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	Private vehicles
47	Lafourche Parish, LA; 9/11/61; Hurricane	Rural Farming	100	23,000 of 37,000	[illegible]	9	0	0	168	370	1,025,000	13	Wet R	Rain	Night	PU	Private vehicles
48	Biloxi, MS; 9/11/61; Hurricane	Urban	7.7	15,000 of 20,000	5	5	0	0	12	2600	75,000	20	Dry S	Clear	Noon Dusk	PU	Private vehicles
49	Gulfport, MS; 8/69; Hurricane	Urban; Industrial	15	10,000 of 10,500	10%-200 90%-0.5	7.5	1	0	24	700	204,000	12	Wet Dry U Eg	Clear	Day	PU	Private vehicles; Death resulted from heart attack during evacuation; died in shelter
50	Cane Run, KY; 7/20/71; Flash Flood	Urban; Rural; Farming	9	1,500 of 1,515	13	36	0	0	48	167	19,500	0	Wet Dry R	Clear	Day Night Dawn	NP	Private vehicles; Slowly developing incident; evacuation occured in stages
51	Cumberland, KY; 12/14/72; Landslide	Urban; Suburban	0.5	150	5.5	1.0	0	0	N.D.	300	825	0	Wet R	Rain Snow	Dusk	PU	Private vehicles
52	Los Angeles, CA; 12/14/73; Dam Break	Urban	0.49	8,500	N.D.	2	2	0	N.D.	17,300	N.D.	4	Dry S	Clear	Day	NP	Private vehicles; Deaths due to driving wrong way into deep water
53a	Florence Co., SC; 2/3/73; Flood	Rural Residential	6	90	6	8	0	0	4.0	15	540	N.D.	Wet R	Clear	Night	PU	Private vehicles
53b	Florence Co., SC; 2/3/73; Flood	Rural Residential	6	9	6	N.D.	0	0	4.0	15	54	N.D.	N.A.	Clear	Night	PU	Boat evacuation

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PU - Plan Used
NP - No Plan

N.D. - No Data
N.A. - Not Applicable

EVENT NUMBER	LOCATION, DATE AND CAUSE FOR EVACUATION	TYPE OF AREA EVACUATED	AREA EVACUATED (SQ. MILES)	NUMBER OF PERSONS EVACUATED	DISTANCE (MILES) EVACUATED	EVACUATION TIME (HOURS)	DEATHS	INJURIES	TIME PERSONS IN EVACUATION STATUS (HOURS)	POPULATION DENSITY #/SQ. MILE	PERSON-MILES x 10^3	TIME BETWEEN EVACUATION AND ONSET OF INCIDENT (HOURS)	ROAD AND CONDITIONS *	WEATHER	TIME OF DAY	EVACUATION PLANS†	REMARKS
54	Minot, ND; 5/69; Flood	Urban	5.0	12,000	1	N.D.	0	0	N.D.	2,400	12,000	N.D.	Wet U	N.D.	Day Dusk Night	PU	Private and supplied transportation; No breakdown
55a	Grand Forks, ND; 4/65; Flood	Rural Residential	0.25	190	2	N.D.	0	0	N.D.	760	380	N.D.	Wet R	Snow	Day	NP	Private vehicles
55b	Grand Forks, ND, 4/65; Flood	Rural Residential	0.25	20	1.0	N.D.	0	0	N.D.	760	20	N.D.	N.A.	Snow	Day	NP	Boat evacuation
56a	Jamestown, ND; 4/69; Flood	Urban	1.0	350 of 354	1.0	24	0	0	72	354	350	N.D.	Wet U	Clear	Day	NP	Private and supplied transportation; No breakdown
56b	Jamestown, ND; 4/69; Flood	Urban	1.0	12	0.5	N.D.	0	0	72	354	6	N.D.	N.A.	Clear	Day	NP	Boat evacuation
57	KY; 7/65 to 12/72; Floods; Tornadoes	N.D.	N.D.	3,400	N.D.	N.D.	0	0	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	Summary sheet data; No breakdown on evacuation modes
58	Aiken, SC; 4/15/69; Flood	Suburban	0.05	35	0.25	0.45	0	0	12	700	8.8	0.5	Wet S	Rain	Night	NP	Very small area evacuated; Private vehicles
59	Milton, FL; 6/70; Flood	Suburban	N.D.	68	N.D.	N.D.	0	0	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	Private vehicles

ROAD AND CONDITIONS * U - Urban Road
S - Suburban Road
R - Rural Road
** - Express Way (Unlimited Access)
Expr[illegible] (Li[illegible] Acces[illegible]

EVACUATION PLANS† P - Plan Available (Not Used)
PU - Plan Used
NP - No Plan

N.D. - No Data
N.A. - Not Applicable