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THE EFFECTS OF A NUCLEAR ATTACK ON RAIL ACTIVITY CENTERS

Prepared for:

OFFICE OF CIVIL AND DEFENSE MOBILIZATION
BATTLE CREEK, MICHIGAN

Under Contract No. CDM-SR-CO-

STANFORD RESEARCH INSTITUTE

MENLO PARK, CALIFORNIA

SRI

July 1961

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Under Contract No. CDM-SR-CO-37

By: *Paul S. Jones*

SRI Project No. IMU-3084

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PREFACE

This report was prepared for the Office of Civil and Defense Mobilization under Contract No. CDM-SR-CO-37. The research was conducted by the Logistics Systems Research group of the Management Sciences Division of Stanford Research Institute. Program direction was provided by Rogers S. Cannell, Manager of Civil Defense Research, and Harvey L. Dixon, Senior Operations Analyst. Paul S. Jones was Project Leader and principal analyst.

The work reported here represents part of a continuing effort to assess the post-nuclear-attack survival and recovery capability of the nation. The report consists of this unclassified volume and classified Appendix D, which is published separately. It is specifically intended to broaden the knowledge of post-attack problems which would face the railroad industry, and relates directly to the report entitled "A System Analysis of the Effects of Nuclear Attack on Railroad Transportation in the Continental United States," published by Stanford Research Institute in April 1960.

Grateful acknowledgment is made for the assistance of the U.S. railroads in providing extensive data on the size and location of classification yards and in reviewing proposed post-attack operating techniques.

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I INTRODUCTION

The development of nuclear weapons and the means to deliver them to far distant targets has completely changed the complexion of civil defense. A great deal of speculation has been directed toward the effects which a nuclear attack might have on the ability of the American economy to rebuild to its present state and sustain the surviving population while supporting extensive military operations.

This entire field is of vital concern to the Office of Civil and Defense Mobilization, which has conducted and supported numerous studies into the scope and effect of various nuclear attacks and the capabilities of America to resist and survive them. Stanford Research Institute has a continuing interest in this effort and has conducted a number of investigations into specific phases of this problem.

In early 1959, Stanford Research Institute began a series of studies directed toward evaluating the ability of the continental United States to survive and recover from a massive nuclear attack. Transportation research has been a key task in this work. At the outset, many informed people feared that a massive nuclear attack might severely cripple this country's transportation system, if not render it unusable.

Planners were concerned about the potential isolation of various broad segments of the country as well as the isolation of small pockets where survivors would have difficulty obtaining sufficient food and medical supplies. Consequently, a research task was designed to evaluate the ability of the transportation industry to function following a massive nuclear attack.

The scope of this task was broad and included investigations of all major modes of transportation--railroad, motor vehicle, pipeline, marine, and aircraft. Railroads were studied first because they generate more ton-miles of transportation service than any other mode and because their use of fuel and personnel is highly efficient. The findings of this initial study, which was directed to long-distance movements, were published in April 1960 in a report entitled, "A Systems Analysis of the Effects of Nuclear Attack on Railroad Transportation in the Continental United States."[1/] As that report points out, for a wide range of attacks,

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1/ That report represents the starting point for the present work and is frequently referred to in following pages as the initial study.

the post-attack rail transportation system would have enough surviving resources to provide long-haul rail transportation to most areas of the country now served by railroads.

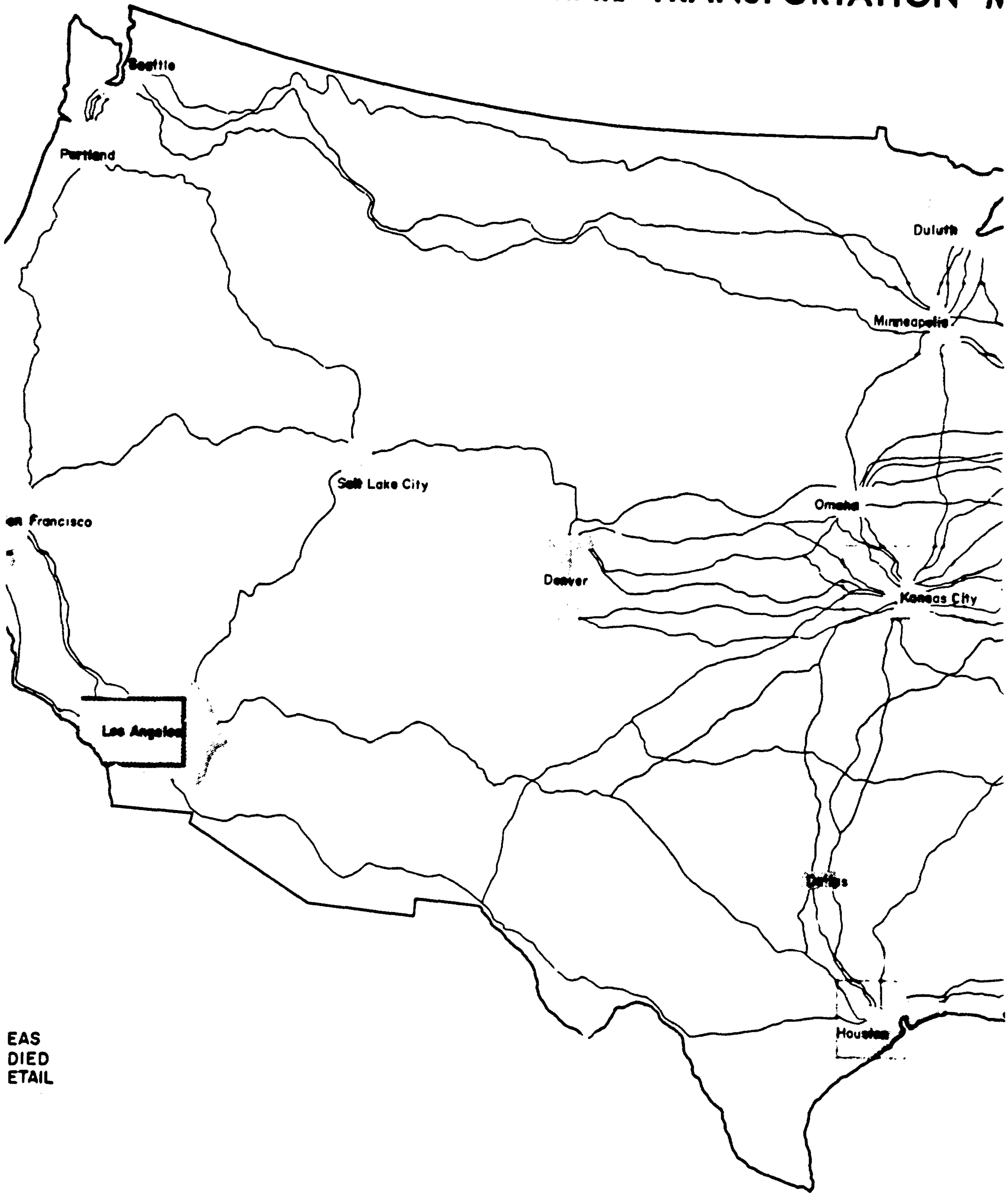
To reach this conclusion, it was necessary to project an inventory of surviving facilities--locomotive units, freight cars, classification yards, repair shops, communication and signaling equipment, and the rail network--into some measure of capability. A rail transportation model was designed to accomplish this measurement. This model is comprised of 37 nodes, each of which is a major rail activity center. These nodes, which represent the points of origination and termination of 60 percent of the rail traffic moving today, are linked together by the principal lines of the 25 largest railroads. These railroads generated 80 percent of all loaded car-miles for the year studied. The map on the facing page is a geographical picture of this model. The specific nodes and links are identified in detail in Appendix B.

In the initial study of post-nuclear-attack rail transportation, capability measurement was directed toward the long-haul movements which would involve one or more model links. Operations within the nodes were not examined in depth. It was determined that connections would exist among the various links which meet at the node, and that surviving yard facilities could be reached from the surviving network. The needs of each rail activity center were considered only to the extent of determining that supplies could be delivered to a point within that center.

A brief look at the distribution of survivors within the rail activity centers indicated that local supply problems might be serious, particularly where large numbers of survivors would be located near a heavily damaged metropolitan area. Supplying food and other essential materials to these people from remote yards and providing means for unloading and transfer to other carriers would pose significant logistic problems. Furthermore, the extent of these problems would have to be determined before the freight load could be realistically divided among different modes of transportation.

The research reported here has therefore been directed toward an examination of the surviving rail network and yard facilities in individual activity centers and an evaluation of their ability, in a post-nuclear-attack environment, to cope with originations and terminations of freight as well as through traffic.

RAIL TRANSPORTATION M



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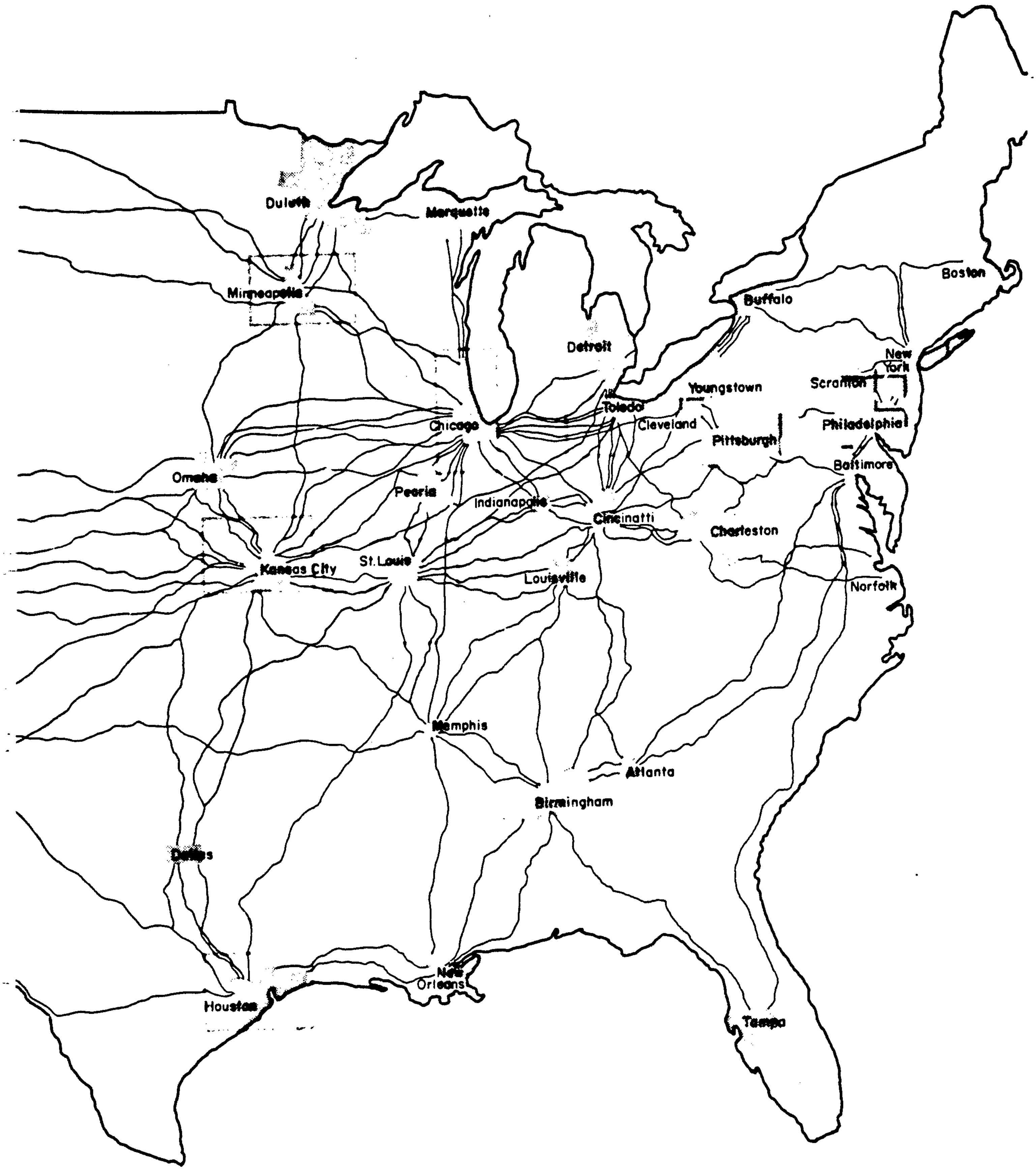
RANSPORTATION MODEL



Scope

The work reported here is the result of an analysis of post-nuclear-attack railroad operation in the 12 rail activity centers indicated on the map on page 3. These particular centers were selected because each would face severe problems following a specific nuclear attack. It is believed that the detailed study of the logistical difficulties encountered at these 12 centers encompasses most of the problems likely to occur at the other 25 centers under these attack conditions. The selected attack, one of four designed by Stanford Research Institute for the Office of Civil and Defense Mobilization, is representative of estimated enemy capability today and is based upon the current military posture of both the United States and the U.S.S.R.[1/]

The analysis has been based upon the transportation of a single commodity--food. Food has been selected since its demand and transportation requirements in the post-attack period can be determined more accurately than those of other individual commodities or groups of commodities. The quantitative capability of the surviving rail system for handling a mix of different commodities can be determined only when the transportation requirements of that mix are known; however, the food analysis is of general interest, since it is based on a study of the surviving facilities in each rail activity center and their necessary interrelationships.

Method of Approach

Early in the research, it became apparent that data available on yards and rail lines were inadequate. Additional information obtained from published documents, maps, and visits to individual railroads and rail activity centers, was combined with that available in the Resource Compendium[2/] to yield a reasonably complete picture of the facilities available in each rail activity center. In the process of combining these data and plotting them on large scale maps, a number of improvements were made to the data contained in the Resource Compendium.[3/]

1/ This attack in the initial report was identified as the Post-1960 Military and Population Attack.

2/ Stanford Research Institute, Resource Compendium for Civil Defense Damage Assessment Program, June 1956.

3/ These revised data are presented in Appendix D, which is classified.

The selected nuclear attack involved 375 4-megaton weapons directed against retaliatory bases and industrial and population centers. Surface bursts were assumed and the damage which the selected nuclear attack would produce in each rail activity center was assessed, considering not only the points at which different weapons would be aimed but also the probability of their detonating at these points.[1/] The hardness of different targets and the influence of surrounding terrain were considered and a number of critical points inspected in order that the assessment of damage might be as accurate as possible. Probabilities of rail facility destruction were then calculated and used to evaluate the availability of critical installations.

The determination of post-attack food transportation requirements was based on the number and location of survivors by county, or similar divisions, and the geographical configuration of surviving yards and rail lines. Interstate food shipments were traced from the point where each rail activity center would be entered to points within 5 or 10 miles of survivors. Supply routes were selected by which food deliveries could be economically made to all survivors and empty freight cars removed. Traffic patterns were established together with yard assignments and requirements for rolling stock. Finally, the capability of the rail facilities to accommodate additional traffic was determined.

1/ The computer program used for assessing damage to yards in the initial study does not include probability factors.

II SUMMARY AND CONCLUSIONS

Study of 12 rail activity centers has led to some specific findings concerning railroad operation following a massive nuclear attack. Although the conclusions reached in this work are restricted to the particular cases studied, the general nature of post-attack conditions expected in each rail activity center could benefit pre-attack planning.

In each of the rail activity centers examined, adequate fixed rail facilities--yards and tracks--would be available after the attack to support the transportation of food to survivors. This transportation would include interstate movements to alleviate regional and state-wide deficiencies as examined in the initial study. It would also include local distribution from the classification center of each rail activity center through support yards to terminals or sidings within reach of individual survivors.

The commitments of rolling stock to the movement of food in the post-attack period are consistent with the present commitments to this same service. In 1959, food comprised 14 percent of the tons moved and 16.5 percent of the carload shipments. This accounted for 23.9 percent of the car-miles of transportation service.

Estimates of rolling stock requirements for both interstate movement and local distribution to all 37 rail activity centers are listed below.

	Interstate Movement1/	Local Distribution	Total	Percent of Surviving Inventory
Locomotive units	1,550	600	2,150	14.0%
Freight cars	96,000	96,000	192,000	16.5

1/ Calculated in the initial study.

Local distribution would require 600 locomotive units in addition to those which are normally assigned to the yards which would survive. Although the requirements of local distribution would not increase the number of freight cars needed for loading each day, it would increase the duration of each trip and hence the number of cars required to maintain a rate of distribution. Although personnel requirements are considered to be very important, their analysis is beyond the scope of this report.

As indicated in Table I, the burden which food would place on the surviving rail system varies widely from area to area. The extent of this burden indicates the approximate capability of the facilities which might be available to transport material for rebuilding damaged cities and restoring their economic activities. In Minneapolis and Kansas City, the burden of food movement might restrict the general rate of recovery by limiting the volume of other commodities which could be transported. In Toledo, survival food could easily be handled by immediately available yards and rail lines with a modest amount of additional motive power, leaving substantial transportation capability for other requirements. Post-attack rail operations would be limited by different factors in different areas. In Los Angeles, the dearth of interstate rail connections would be a critical problem. Adequate yard facilities would be the major burden in Kansas City. Rail movements in Pittsburgh would be limited by the capability of a local rail line.

The conclusions presented here are based upon transporting survival food by rail alone. In some cases single cars would be delivered to the ends of long branch lines. Clearly this represents poor utilization of motive power and train crews. In an actual post-attack situation, it is likely that a mix of transportation modes would be used to accomplish more efficient food delivery to survivors.

In several areas there are specific problems which warrant careful pre-attack planning. Los Angeles would have to contend with at least temporary isolation of half of its survivors. New York City would have to transport almost 8,000 tons of food per day over water to survivors on Long Island which would not have adequate port facilities. Railroad operations in the San Francisco area would be hampered by a 220-mile supply line from the principal yard to the surviving population. Post-attack operations in the Philadelphia area would be a logistic nightmare.

Several areas have one or more extremely critical facilities. St. Louis traffic would be limited by the ability to move trains across 2 single-track bridges at Alton and Illmo. Careful planning would relieve this situation by permitting increased traffic density; however, this

Table I

THE BURDEN IMPOSED BY SURVIVAL FOOD TRANSPORTATION ON POST-ATTACK RAIL ACTIVITY CENTER FACILITIES

Rail Activity Center	Switching Load As a Percent of Surviving Capability1/	Train Density As a Percent of Capability of Most Critical Rail Line2/	Additional Locomotive Units Needed3/
New York City	31%	31%	55
Philadelphia	10	18	35
Baltimore	8	13	5
Pittsburgh	19	40	15
Toledo	9	13	3
Chicago	17	26	15
Minneapolis	54	40	24
St. Louis	22	66	30
Kansas City	76	33	10
Houston	15	67	20
Los Angeles	17	80	38
San Francisco	6	27	24

1/ Based on capability of only those yards in the classification center with an average holding time of 2 days as explained in Section IV, Method of Analysis.

2/ Based on the post-attack capability of the most critical rail line.

3/ For delivery of food within the rail activity center and for switching service in support yards.

increase in density could be accomplished only by accepting additional delays and reducing the capability of yards and rolling stock. The Baltimore, Los Angeles, and San Francisco areas each face the problem of access to large numbers of survivors depending upon the availability of a single critical rail line, near an expected target. In the heavily damaged Northeast, transportation between rail activity centers could be critical, for if the Delaware River bridge north of Trenton were lost, there would be no rail communication between New York and Philadelphia except through the Scranton rail activity center.

These problems point to the critical need for competent post-attack management capable of taking decisive action on the basis of fragmentary information. Due to the fact that home offices are located in large cities, most home-office personnel would be lost in the hypothetical attack. This loss of home-office personnel would place the burden of post-attack action on division management. From the surviving yards, local management would have to select a classification center consisting of yards with adequate capacity to handle both local and long-distance movements. This center would likely comprise yards formerly operated by different railroads. Workable organization and communication would have to be established for these yards. Agreement would have to be reached on procedures for handling both long-haul and local traffic. Communication lines would have to be restored or established, and the functions of the various support yards would have to be defined. Concurrently, available rail lines would have to be determined and inspected. Traffic patterns would have to be established to best use the available resources. Both local and long-distance dispatching would be important to avoid unnecessary congestion or even blocking in critical areas. Dispatchers would be routing and scheduling trains over unfamiliar rail lines having frequent detours and would, in addition, be dealing with wide volume fluctuations. Available rolling stock would need to be effectively utilized and personnel induced to perform assigned tasks despite continuing hazards. Railroad managements would face these problems, not in isolated areas only, but throughout the country. Planning and training offer the best solutions to the management problem. Both are relatively cheap, particularly when the alternatives are evaluated.

Adequate communications would be vital to good management. Short-range communication by VHF radio appears both feasible and workable, and substantial amounts of equipment are now available. Although they have not been examined in this research, long-distance communications are extremely important and merit careful investigation. Adequate signaling depends upon the availability of short-range communications and, if visual signals are to be used, some source of electric power. Stand-by electric-power-generating equipment would enhance the capability of many critical rail lines by restoring visual signaling systems and thereby permitting higher speeds and shorter headway between trains.

Several areas would require fast freight-transfer devices to permit large volumes of freight to be shifted from rail cars to other carriers. Both piggyback and containerization offer solutions; however, both systems depend upon special terminals equipped with ramps or transfer devices and adequate storage areas for the intended volume of traffic. Consideration should be given to the capital needed to locate these facilities outside target areas or to stockpile mobile transfer equipment which could be used to establish terminals in remote areas.

Although radioactive fallout is a serious problem, it need not prevent operations within a rail activity center. Operations could begin before survivors in each rail activity center have consumed their available food stocks. The fallout level in most surviving yards would permit re-entry within 1 week for work in the open. Repairs to many damaged facilities could begin in 1 to 3 months. The time at which these would be available for service would depend upon the adequacy of supply of repair parts and materials.

The research on which this report is based has shown that, for the areas studied, food could be delivered by rail to within a few miles of nuclear attack survivors. The distribution patterns postulated present a basis for further study by civil defense planners when considering other modes of transportation. The complexity of the local distribution of a single commodity demonstrates the need for careful organization and effective management of transport systems following a massive nuclear attack, for, in addition to meeting the emergency needs of survivors, transportation would be required to support a reconstruction program.

III EFFECTS OF THE NUCLEAR ATTACK

Although it is assumed that the rail system would not be a primary nuclear target, rail facilities would suffer destruction and damage from weapons directed against nearby targets.

Damage to rail facilities by nuclear weapons can take a variety of forms. Track could be considered destroyed when the rails cease to be straight and parallel or when the roadbed could not provide adequate support. Debris from adjacent structures could also render track unusable. Similarly, a yard could be effectively destroyed by debris from rolling stock and structures even though most or all of its track remained intact. Loss of signal and control equipment would make operation difficult though possible if tracks remain clear or could be cleared without subjecting personnel to undue hazards. Because of the extent of the rail system in terms of alternative routes and parallel facilities, total destruction would be impossible for the scale of attack under study.

The analysis presented in this report is based on the attack referred to in the initial report as the Post-1960 Military and Population Attack. The targets for the attack represent a combination of retaliatory bases, industrial centers, and population centers. The attack design envisions the delivery on targets of 375 missile-mounted weapons with an aggregate destructive power of 1,500 megatons. Some of these weapons would be directed against specific targets, such as SAC or missile bases. Others need only fall within a fairly large area to accomplish extensive damage. For example, the densely populated New York metropolitan area is almost 40 miles in diameter. The aiming problem for a single weapon would be relatively easy; however, as more weapons are assigned to this large target in order to increase damage, the constraints on individual weapons become more limiting.

The hypothetical attack consists of 375 aiming points expressed in terms of Universal Transverse Mercator coordinates. It is, of course, possible to assume that all weapons would fall and detonate at the prescribed aiming points. While such a condition represents maximum destruction to primary targets, it does not necessarily represent maximum destruction to secondary targets such as rail facilities. A realistic evaluation of the potential damage to rail facilities requires consideration of the factors which would cause the nuclear weapons to detonate at other than the prescribed points.

The point of detonation is but one of several factors which influence the amount of damage which a weapon will inflict on nearby rail facilities. The destructive effects of the weapon depend upon the altitude at which it explodes, and on the nature of the soil and terrain both near the weapon ground-zero and near the rail facilities. Adjacent buildings or other structures can cause severe damage by collapsing on and strewing debris about railroad areas.

Peculiarities of local conditions and dearth of experimental data make it difficult to prescribe damage as a function of distance from point of detonation. Among other things, the extent of damage depends on the physical configuration of the rail equipment--orientation of rolling stock and presence of rolling stock on track.

Finally, there is the continuing hazard of radioactive fallout. The reader is referred to the initial study for a detailed treatment of this subject. The levels of radioactive fallout, the protection afforded by different rail equipment, and the calculation of permissible re-entry times have been based on that work.

Weapon Errors

It will generally be considered that all weapons burst at the surface of the earth. Although different types of primary targets would be best destroyed with a variety of heights of burst, the damage to rail targets does not vary a great deal. In specific cases where a particular facility is critical, consideration has been given to the influence of different burst heights.

In a real attack all nuclear weapons would not detonate at their points of aim. Among other things, the size of the error depends upon the accuracy of the guidance system, which can best be evaluated in terms of statistical probability. Missile accuracy is normally expressed in terms of circular probable error (CEP). The CEP is the radius of the circle which would enclose 50 percent of the impact points of a large number of weapons aimed at the same point. The impact points are assumed to follow a circular gaussian distribution.[1/]

To determine whether a point target offset from the point of aim would be destroyed by a weapon whose aiming point and CEP are known, two additional facts are needed:

1/ H. H. Germond, The Circular Coverage Function, RM 330, The RAND Corporation, 26 January 1960, Unclassified.

1. The offset distance or the distance between the aiming point and the selected target, and

2. The lethal radius of the target.

The lethal radius is determined from the vulnerability of the target to destruction by a nuclear weapon. If the nuclear weapon falls within the circle described by the lethal radius around the target, the target would be destroyed.[1/]

In dealing with a linear target, such as track, angular displacement between the point of aim and the target becomes less important. For these targets, the lethal radius is the perpendicular distance within which weapon detonation would cause destruction. Linear gaussian probabilities were used for these targets.

The vulnerability of a target would be increased if it lay near the aiming points of more than one weapon. In computing the probability of survival in such cases, it has been assumed that all weapons act independently. An error affecting one weapon would not likely influence either the size or direction of the aiming error for another weapon. The probability of target survival from each weapon has been calculated separately. The product of these factors represents the probability that a target would survive the effects of all of the weapons.

This statistical framework has been used to describe a "gray area" around each aiming point--the land in which a target would not certainly be destroyed but where its survival and post-attack availability would be subject to doubt.

Weapon Effects

The results of a nuclear detonation which are most likely to cause damage to railroad facilities are the blast wave or shock front and the thermal radiation.[2/]

1/ The RAND Corporation, Offset Circle Probabilities, R-234, 14 March 1952, Unclassified.

2/ These effects are presented in considerable detail in the following publications:

Blast Energy

The blast wave is like a "moving wall of highly compressed air." It is produced by the enormous pressure, extremely high temperature, and large volume of the products of the nuclear explosion. This wave decays rapidly as it travels from the point of detonation at decreasing speed. There is some confusion concerning the nature of this shock wave at very high pressures because of the difficulty of making accurate measurements. Since most rail targets would be destroyed by a peak overpressure in excess of 25 psi, this study need consider only the low pressure regions which are relatively well understood.

In addition to distance from ground zero, the magnitude of this blast wave--peak overpressure--depends upon the height of burst of the weapon, the topography of the region, and the physical condition of the surface. The data presented in Figure 1 represent an average value of peak overpressure as a function of distance alone. Because of the wide and frequently unknown variation in terrain, these average values were used in this study.

The fast moving pressure front has considerable dynamic energy, of major importance in evaluating damage to drag-sensitive structures such as towers and bridges. Under certain conditions of weapon yield, height of burst, and ground range, dynamic pressure could cause greater damage to rolling stock than peak overpressure. All available evidence, however, indicates that peak overpressure is a more important criterion when all conditions of yield and range are considered for all railroad targets. Therefore, dynamic pressures have not been specifically examined in this study.

Thermal Energy

The extremely high temperature of the nuclear fire ball contributes to the release of as much as one-third of the weapon's energy in the form

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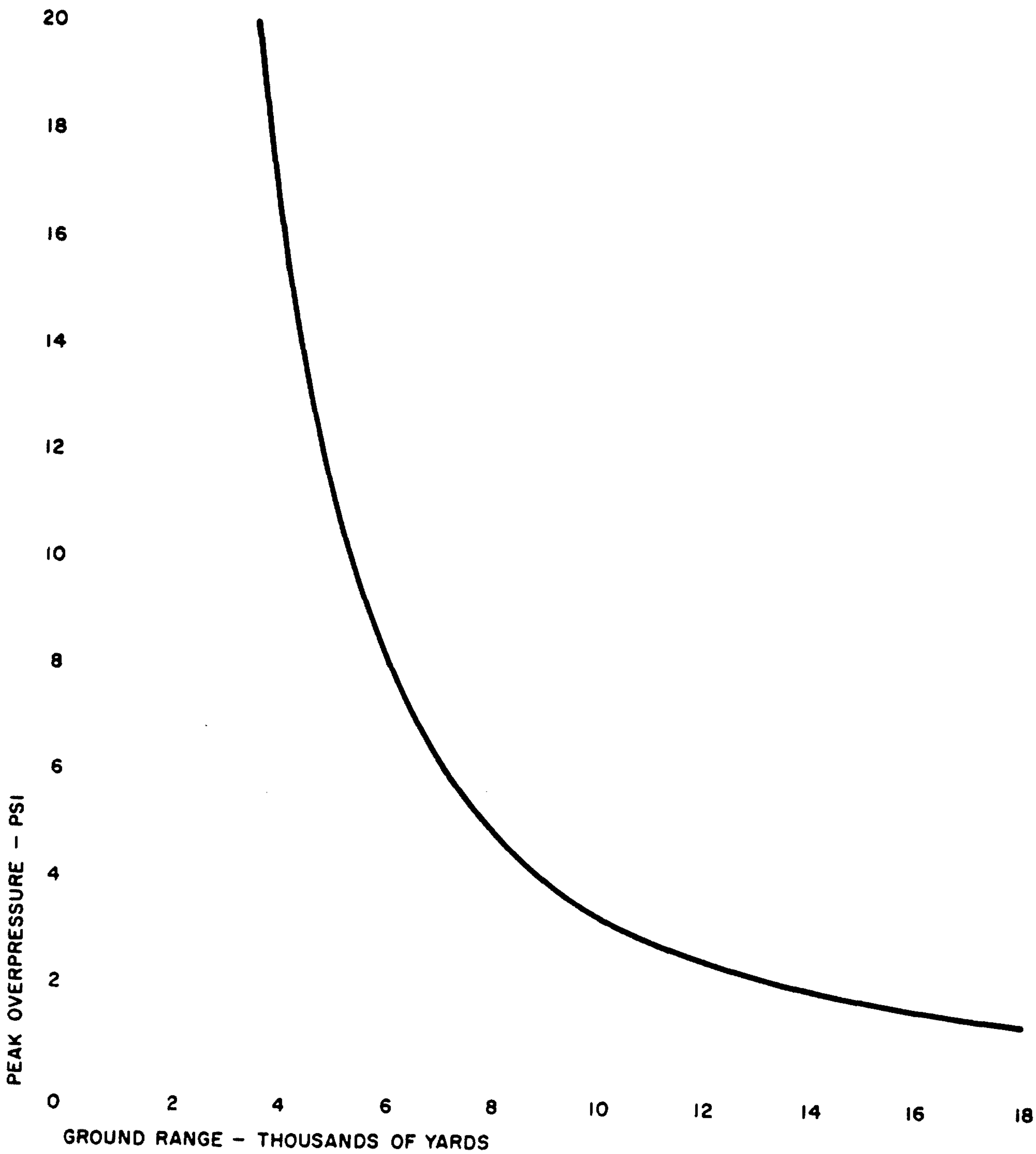
U.S. Atomic Energy Commission, The Effects of Nuclear Weapons, June 1957, Unclassified.

Department of the Army, TM 23-200, November 1957, Capabilities of Atomic Weapons (U). Confidential.

James F. Moulton, Jr., Nuclear Weapons Blast Phenomena, DASA 1200, March 1960, SECRET, RD

FIG. 1
BLAST OVERPRESSURE

4 MT WEAPON
SEA LEVEL SURFACE BURS.



of thermal radiation. This thermal radiation can cause severe burns to exposed persons, blister paint, char wooden surfaces, and ignite readily combustible matter such as paper, wood shavings, and refuse.

Thermal radiation, however, is of short duration and is unlikely to ignite rolling stock or the ties in the roadway at distances where this equipment would not be destroyed by the blast wave. No experimental evidence has indicated that ties can be ignited even at extremely short distances from ground zero. Therefore, thermal radiation has not been considered when assessing the damage to rail facilities which results from a nuclear explosion.

Hardness of Rail Facilities

Predictions of damage caused by a blast wave are very uncertain. The probability of survival depends upon the lethal radius, which, in turn, depends upon an individual facility's resistance to the blast wave, commonly referred to as hardness. The hardness of the various rail components is discussed below to give the reader an impression of the reliability of the lethal radii used in this study.

Track

Experimental data on track hardness are not satisfactory. Since there are no rail lines leading into the Nevada test area, rolling stock subjected to nuclear weapons has been placed on short sections of definitely inferior track. The presence of rolling stock on the track greatly increases damage as the blast force is transmitted to the rails through wheel flanges. Therefore, in evaluating the probability of destroying track, it is necessary to consider the likelihood that a train will be near ground zero at the time of the attack.

In a main track, the rails are securely anchored to the ties. The rail presents a very small profile to the blast wave and the ties, largely buried in ballast, almost none. This combination represents a very hard target.

A careful examination of available data[1/] indicates that track can be reasonably expected to survive a peak overpressure of 25 psi. The

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1/ Project 3.6, Operation Upshot-Knothole, WADC TN-55-422, The Effects of Nuclear Weapons, Confidential.

lethal radius for track has therefore been set at 3,000 yards or 1.7 statute miles for a 4-MT weapon. It appears unlikely that well-constructed track with rolling stock on it would be destroyed below an overpressure of 10 psi. The lethal radius for occupied track is therefore 5,500 yards for the weapon size assumed in this report. For these conditions the probability of track survival as a function of the distance from the point of aim is plotted in Figure 2.

Yards

In the initial study the railroad yards were assigned a vulnerability code 3. This meant that if subjected to a peak overpressure of 7.0 psi or greater, a yard would be considered unavailable or destroyed. If the blast wave decayed to 3.2 psi before reaching the yard, the yard would be considered usable. Intermediate overpressures would produce a range of damage. These figures represent a compromise since actual damage would depend upon a number of factors. The characteristics of each car in the yard would be important--its type, whether it is loaded or empty, and the characteristics of the load with respect to rigidity, center of gravity, and gross weight. The position of each car would also be important--its orientation to the weapon's ground zero, and the extent to which it is shielded by adjacent cars and structures.

An evaluation of the very limited experimental data does not provide any basis for challenging the vulnerability code 3 used in the initial study. The lethal radius for yard destruction is considered to be 6,500 yards and that for damage, 10,000 yards. In Figure 3, the probability that a yard would survive destruction or damage is expressed in terms of its distance from the point of aim.

FIG. 2
PROBABILITY THAT RAILROAD TRACK WOULD SURVIVE DESTRUCTION

4 MT WEAPON
CEP=4000 YD

LETHAL RADII
UNOCCUPIED TRACK 3,000 YD
OCCUPIED TRACK 5,500 YD

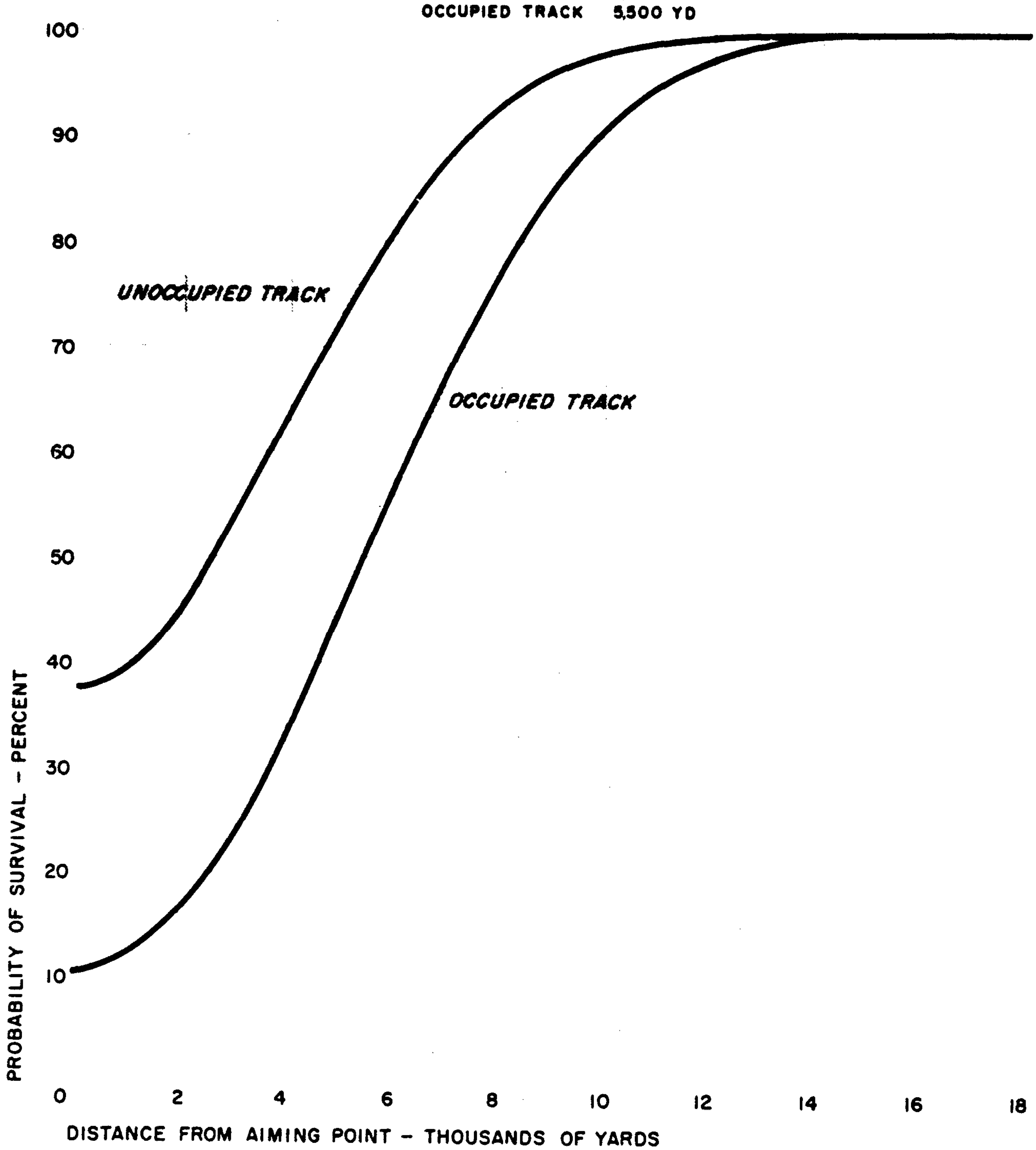
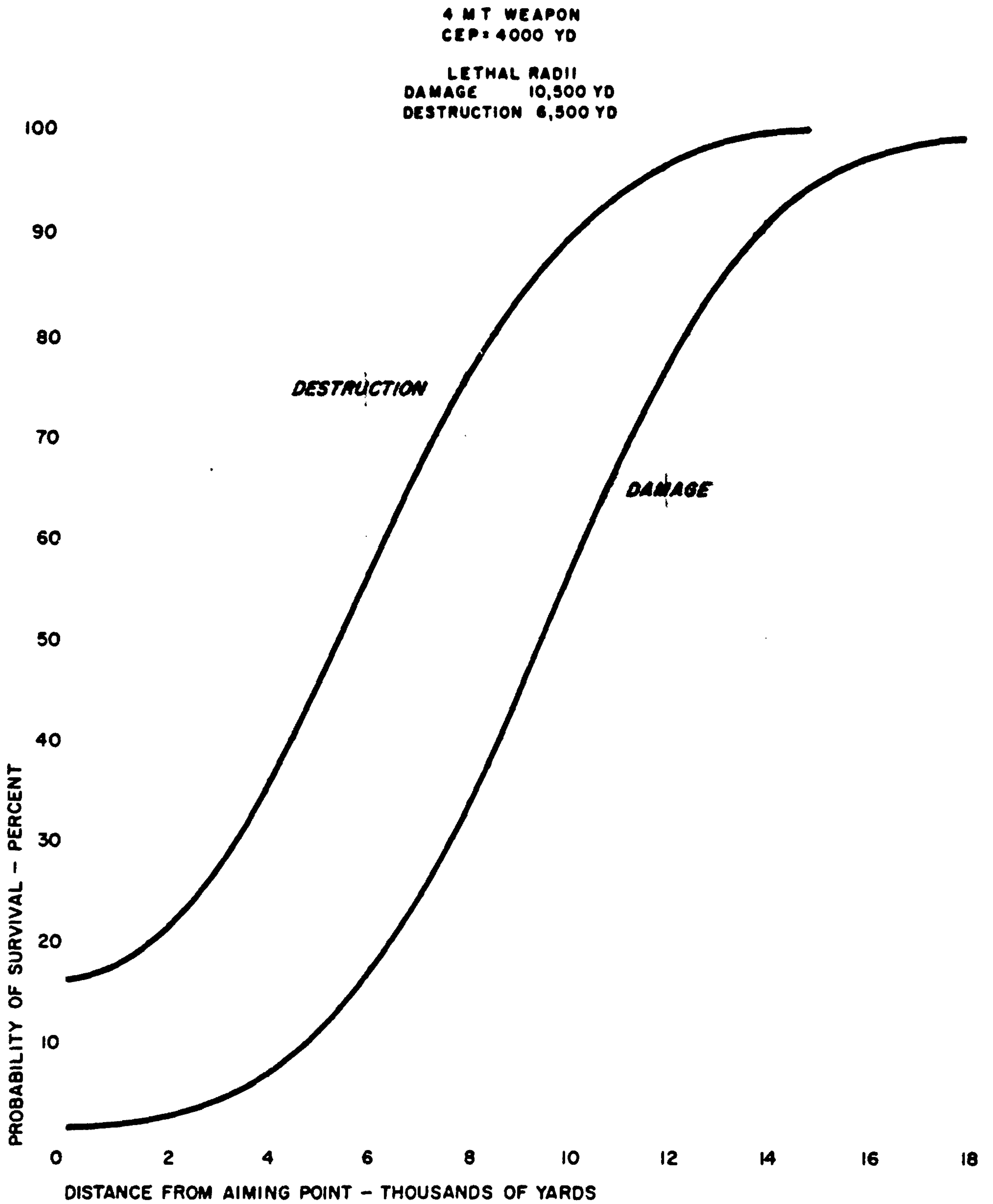


FIG. 3
PROBABILITY THAT A RAILROAD YARD WOULD SURVIVE DAMAGE OR DESTRUCTION



IV METHOD OF ANALYSIS

An examination of the population distribution to be served and the physical facilities in specific rail activity centers which might survive a nuclear attack clearly indicates that there are major logistic problems to be overcome. For any one rail activity center the more critical rail components appear to be track and yards because motive power, rolling stock, and personnel could be brought in from other areas. Equipment maintenance could be performed elsewhere. If, however, rail transportation is to be established, rail lines and yards must be reasonably intact. Since radioactive fallout intensities are likely to be high in areas where tracks are damaged, and it is not reasonable to expect that new track can be laid in sufficient time to alleviate any early post-attack needs, post-attack transportation planning must be based on only surviving facilities.

In order to make a realistic evaluation of post-attack operations in a rail activity center, the geographical pattern of transportation requirements should be established and the extent and capability of surviving rail facilities determined.

Transportation Requirements

Transportation requirements are inherently geographical. They depend upon origin, destination, route, and schedule of shipments for all commodities.

It is difficult to describe pre-attack freight movements within a rail activity center even with a detailed knowledge of industry location, output, and shipping practice. Without these data an accurate description of rail movements in the post-attack period would not be possible.

By making a few plausible assumptions, however, it is possible to estimate a distribution pattern for food in the early post-attack period. Food transportation requirements can be estimated from data on blast and radiation survivors by county. Among the assumptions needed to establish these requirements are:

1. Survivors would not be evacuated from the immediate vicinity of the rail activity center. It can be seen from the map of the Rail Transportation Model on page 3 that rail activity centers typically cover several counties, so that local evacuation would not invalidate this assumption.

2. To the extent possible, long-distance overland shipments would move by rail. Rail freight offers economy in two vital areas--fuel and manpower. In addition, a diesel locomotive provides the crew with better fallout shielding than a truck.

3. Rolling stock is not a limiting resource. Economy of handling and radioactive exposure might dictate that the food be moved in the rail car as near to the final destination as possible. It is recognized that in a real situation, other modes of transportation would be used for delivery to the point of consumption and that local conditions would dictate where and how the transfer between modes would be accomplished. The assumption of unlimited rolling stock tests the capability of the railroads to the limit of their rail and yard facilities.

4. Food production within the rail activity center would not be significant. This is a reasonable assumption for highly developed metropolitan areas as well as centers, whose farm land, though substantial, is incapable of meeting the food requirements of a large urban population.

On the basis of these assumptions, it was possible to establish a steady-state food movement pattern with food supply equal to the rate of consumption. The quantities of food which would have to be delivered were determined on the basis of 6 pounds per capita per day.[1/]

The pattern was divided into two parts for purposes of analysis, interstate movement and intrastate movement. Interstate movement is comprised of those long-distance movements necessary to alleviate shortages on a state-wide or area-wide basis. The quantitative extent of these movements was developed in the initial study. Intrastate movements are those necessary to distribute food from receiving centers or warehouses to the surviving population. The extent of these movements was developed in this research for each of the 12 rail activity centers examined.

Capability Measurement

Locomotives, freight cars, rail lines, yards, and personnel (not considered in this study) are needed to distribute food throughout a

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1/ The basis for this figure and the types of food used are developed in Section VIII of the initial study.

rail activity center. In order to express requirements quantitatively, it is necessary to have appropriate measures of capability. The measures used here are, in some cases, different from those used in the initial study for long-distance movements. Changes have been made to reflect the increased damage, more numerous detours, more frequent delays, and congestion which could be expected near a heavily damaged metropolitan area.

Motive Power

Motive power capability in terms of tons of freight per hour depends upon the load per car, speed, and grade in addition to locomotive characteristics and equipment utilization. This subject was treated in considerable detail in the initial study and will not be repeated here.

A single 1,500-horsepower locomotive unit can pull between 25 and 30 freight cars, each with a mean load of 38.8 tons of food, over grades of 1.5 percent or less at reasonable operating speeds. Motive power assignments within the rail activity centers studied were governed by this capability except where steep grades are known to exist.

Single-unit locomotives would probably be used for local delivery since this entails considerable switching along the way. This practice would increase train densities on the limited number of available rail lines, but since a large percentage of the time required for local deliveries would be switching me, the short trains seem to offer the most logical solution. An average set-out and pickup of cars at a way-switching point requires about 20 minutes today. Forty minutes has been allowed for this operation in a damaged rail activity center.

The situation is different where freight cars are transferred from one yard to another within a rail activity center. In the absence of way switching, the use of multiple-unit locomotives would result in lower train densities on critical rail lines and conservation of operating personnel.

Yards

The most useful measure of yard capability would be an expression for determining mean freight car turnover or the average number of cars which can be processed per unit time. A great deal of research effort has been expended on this problem without producing a reliable and usable capability measure. Mean turnover rate depends on the manner in which the yard is used, its relationship to other yards, the type of traffic which it handles, and the characteristics of that traffic. In the initial report, an estimate was prepared for interstate movements. It is unlikely that sorting could be accomplished as quickly for local deliveries as for interstate movements because of the dependence on other facilities and the adverse effect of poor communications.

As a result of many discussions with railroad personnel, intensive study of the 12 rail activity centers, and a statistical analysis, a mean post-attack turnover rate of 2 days per car has been selected for classification yards. This rate is intended to include both local and long-haul traffic. No measure of turnover has been developed for terminal and support yards, as the variety of local conditions would invalidate a mean rate.

The general pattern of post-attack freight classification is likely to be very different from present day operations. Many of the large classification yards on which today's operations pivot would be lost. Communication lines would be down. Lack of electric power could deny the use of retarders and other automatic devices in the more modern yards. Finally, the method of handling freight might be so different as to require a revision of operating techniques. Nonetheless, the basic functions of classification yards and terminals must be provided.

Based upon size, location, physical facilities, and traffic patterns, a certain yard or yards would have to be designated as a classification center and be assigned the classification of trains. Long-distance (interstate) trains would be classified and redirected. Freight cars for local termination would be directed to terminals or support yards. Local originations would be sorted and included in the appropriate outbound trains. This local traffic could not move without the services of terminal and support yards. The post-attack assignments for yards need not follow their pre-attack function. For example, a surviving major classification yard near a city might be on the dead end of a track as a result of weapon damage. Such a yard might best serve as a terminal, utilizing its storage capacity to simplify the problem of moving traffic in and out. The yards in the classification center would likely be outside the city near the "belt line"--the shortest rail route around the damaged metropolitan area available in the post-attack period. Here, these yards could readily receive interstate shipments, perform en route classification, and sort cars received for local delivery. Where the classification center function is shared by several small yards, the problem of coordination would become intense, especially if these yards were widely separated or had poor communications.

If delivery points were freight terminals converted from passing sidings, industrial sidings, or other makeshift switching tracks, a support yard would be needed to provide some switching and the storage necessary to accommodate a realistic delivery schedule.

Efficient use of the surviving network and available rolling stock may dictate that cars for some delivery points be held for one or more days so that a full train can be dispatched.

Rail Lines

As presented in the initial report, rail line capability depends upon number of tracks, spacing of sidings, type of signaling, type of dispatching, and train speed. Lacking details on siding configurations, estimates of rail line capability were in terms of number of tracks, type of signaling, and type of dispatching. These were based on average main line speeds of 23 miles per hour which could not be achieved on rail lines in and around rail activity centers.

Careful analysis of the conditions likely to exist in post-attack rail activity centers has led to revision in rail line capability because of reduced speeds and the high level of way switching expected. For long-distance movements, an average speed, less way-switching allowance, of 15 mph has been used. Where way switching is necessary, 10 mph has been used. Using these lower speeds, the capability of a single track has been reduced from 24 to 15 trains per day and double track from 72 to 45 trains per day.

Analytical Procedure

In order to establish a logistic system for the delivery of vital food supplies to all survivors, the rail activity center is analyzed in the light of the availability of rail facilities and the location of survivors. The solution to this problem is expressed in terms of the rolling stock required to supply the food and the load which is placed on surviving yards and the available rail network. Interstate movements as well as movements within the rail activity center are considered in integrating the local supply program into the entire rail system. The capability of the rail activity center to handle traffic in addition to food can be evaluated by knowing the percent of total capability required to move survival food. Finally, the facilities which limit capability can be identified.

Mapping the Problem

The first step of the analysis was directed toward obtaining an accurate post-attack picture of the rail activity center. The aiming points of the weapons assigned to the vicinity of each rail activity center were carefully located on Army Map Service (AMS) Series V-402 maps (Scale: 1:500,000). Knowing weapons characteristics, as discussed in Section III, it is possible to plot areas of heavy urban destruction around each point of aim. In these areas, railroad tracks and yards would likely be covered with debris, rendering use impossible until extensive clearing had been performed.

A belt line around the damaged area was selected as a focal point for post-attack rail activities. This line would afford access between incoming interstate lines and local lines by which food might be shipped to survivors. Where the belt line would pass near the area of heavy damage it was necessary to assess the probability that it would be available in terms of weapon errors and the lethal radii[1/] of adjacent urban and railroad structures.

It was next necessary to determine the availability of yard facilities. A classification center was needed for each rail activity center to classify both interstate and local traffic. The locations and compositions of these centers would depend on both the characteristics of the surviving yards and the requirements for post-attack transportation. Where possible, yards from the Resource Compendium[2/] were used, since they represent major classification yards. Sometimes it was desirable to combine these with adjacent terminals and support yards for increased capacity. In other cases no suitable classification yard would survive and the classification center would have to be an amalgamation of several small yards. As the number of yards in the classification center increased, the coordinating problems would become more severe. Several yards might operate in parallel in receiving, sorting, assembling, and dispatching trains, or each yard might perform just one step. Good communication and coordination would become extremely important.

1/ The lethal radius is defined as the distance from an object within which a nuclear weapon would have to detonate to cause that object's destruction.

2/ See Appendix A, "Sources of Data."

Those yards not in the classification center would act as support yards and terminals. The larger of these could receive full trains and perform some additional sorting by destination siding. The small yards could merely perform interim storage to facilitate delivery schedules.

Figure 4 illustrates the type of map which might result from this analysis. The belt line around the damaged area has been selected. Even if the main track through the city were not destroyed by the nuclear weapon, it would likely be impassable due to debris. Because of their proximity to interstate lines and their potential capability, the 3 yards at the top of the page have been selected as the classification center. Other yards are designated as support yards. The yard on the fringe of the damaged area might serve as a terminal for the adjacent city since its outer end might be usable or easily cleared.

In determining the yard capability of the rail activity center, the classification center and the support yards were treated separately. Diversion of through traffic to a support yard for classification would probably not ease the load, since the sorted cars would have to be reassembled into outgoing trains. This activity would probably require that they be returned to the classification center for combination with the output of other small yards.

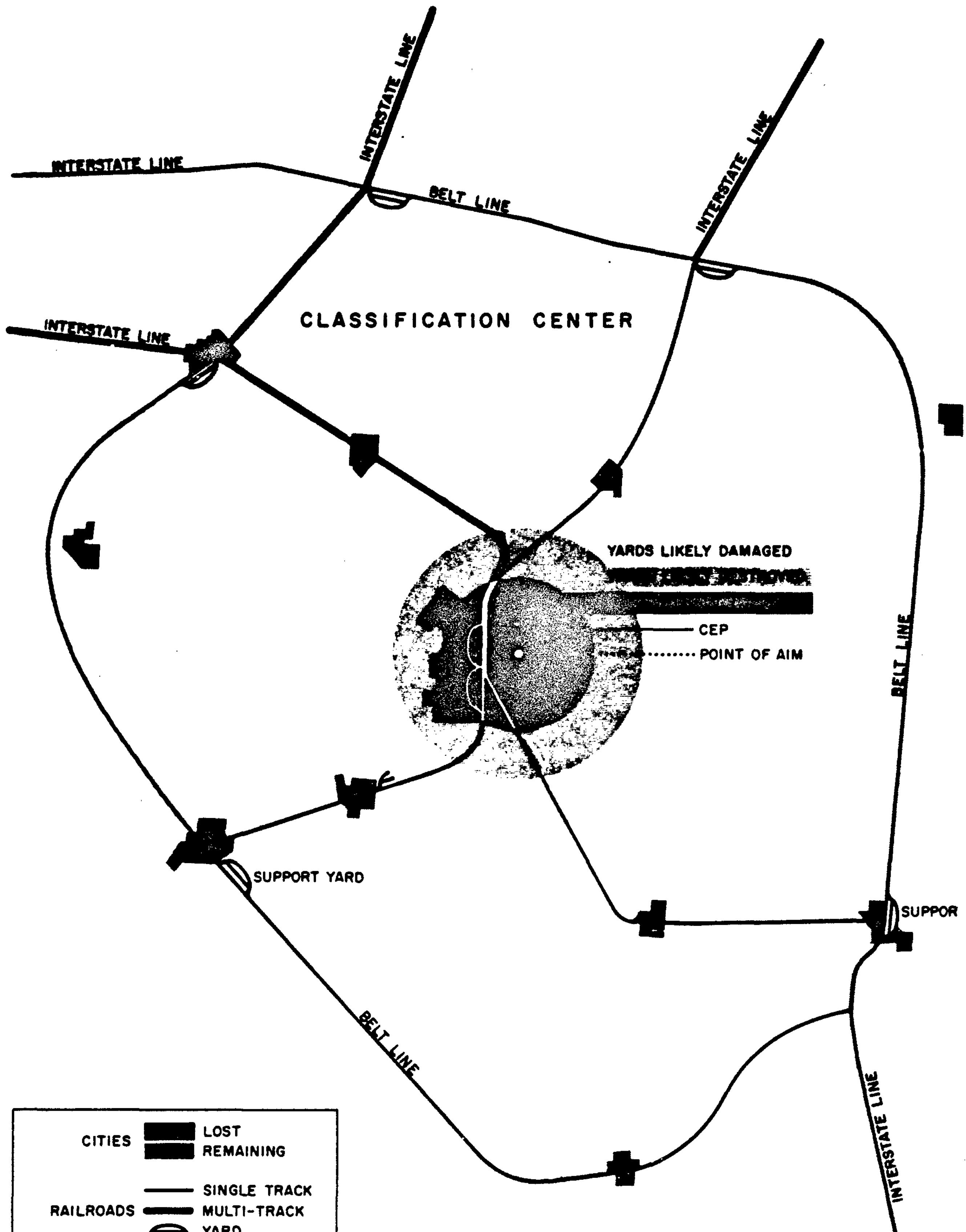
Because of the diversity of industrial sidings, way-switching track, and small yards which have not been identified, the yard capability of a rail activity center would be dictated by the classification center and not the support facilities. A number of locations were inspected in the Philadelphia, St. Louis, Kansas City, Houston, Los Angeles, and San Francisco rail activity centers to determine whether they could accommodate post-attack freight traffic. All of those inspected were found to have suitable facilities for handling at least 10 carloads per day of inbound freight. Most could handle substantially more.

Where doubt existed as to the survival of a particular facility, probabilities were calculated in the manner outlined in Section III, "Effects of the Nuclear Attack." Only those facilities whose probability of survival would be 50 percent or better were used in the analyses.

Determining Transportation Requirements

Since it was assumed that all food would come from outside the rail activity center, there were two possible sources--local trains coming from storage areas within the state, and long-distance trains

FIG. 4
ANALYTICAL PROCEDURE



arriving on principal interstate lines. In either case, freight cars loaded with food would arrive at the classification center for local distribution.

The distribution requirements were determined on the basis of survivors per county whose numbers were available from a computer program developed by Stanford Research Institute. Within each county, survivors were divided among cities and towns according to their present population and proximity to the points of aim. Transportation requirements were then established on the basis of 6 pounds of food per capita per day.

Knowing the origin and destination of freight, it was possible to plan and schedule routes for delivery of this freight. For the distant areas, scheduling was important. A typical delivery run might involve a round-trip distance of 300 miles, requiring 22 hours plus switching time of 15 hours to set out the 25 loaded freight cars and pick up an equal number of empties. It would be clearly wasteful to make two trips with 12 cars each in place of the single trip. It would also be wasteful to pull 50 cars with a two-unit locomotive which is not later split for switching purposes. Scheduling for nearby areas is more flexible and can be adjusted to improve the utilization of the available locomotive units.

The completed delivery schedules yielded a great deal of valuable information. Traffic density on surviving rail lines could be estimated. Locomotive requirements to service the rail activity center could be derived, both for yard operation and for distribution. Finally, the nature of the switching operation in the various yards could be approximated, as could the degree of interyard coordination needed. The average yard holding time of 2 days was in part a product of these schedule analyses.

It must be remembered that the conclusions derived from these analyses are based on a single specific nuclear attack, the movement of a single commodity, and the use of a single mode of transportation. Different attack assumptions, consideration of other commodities in addition to or in place of food, and the introduction of motor vehicles would change the specific results, although they might not change the nature of these results.

V ANALYSIS OF RAIL ACTIVITY CENTERS

The results of detailed analyses of 12 selected rail activity centers are presented in this section together with maps of each showing post-attack rail transportation. While these maps do not include all surviving facilities, they are sufficiently detailed to give a visual impression of post-attack problems. The discussion of individual rail activity centers is limited to important problems and peculiar characteristics. The method used in the analyses has been described in detail in Section IV.

New York City Rail Activity Center

In spite of the heavy concentration of weapons in the New York area, it is expected that there would be over 6 million survivors in northern New Jersey, Westchester County, New York, and on Long Island. Interstate rail service would be available to these survivors over one single-track line from Buffalo (through either Port Jervis or Poughkeepsie); a single-track line from Scranton (through Dover); possibly a double-track line (53 percent probability) from Philadelphia (through Somerville) and two single-track lines from Boston (through Towners and Danbury).

No combination of the surviving yards within the rail activity center would make a suitable classification center. Although the yards in the Perth Amboy area have a capacity of 5,000 cars, they are in an awkward position, not readily accessible to main lines from Buffalo, Boston, and Scranton. The two yards at Port Jervis and Maybrook are more likely candidates. They have a combined capacity of 7,600 cars and a much more favorable location.

Distributing food to the surviving population would impose a load of 1,166 cars per day on the classification center. Of this number, 475 carloads of food per day would have to be distributed throughout the rail activity center. Delivery to points in Middlesex, Somerset, and Union counties, New Jersey, could be accomplished from support yards at Perth Amboy and Port Reading. Staten Island traffic would have to move by water or by truck over the Outerbridge crossing. The 94 carloads of food per day needed in the northern New Jersey counties could best be supplied from Port Jervis or Maybrook, utilizing the Paterson yard for support. Daily 113-car food trains could be dispatched to Mt. Vernon for delivery to Westchester County, New York. The use of these long trains would relieve the traffic load on the rail line between Poughkeepsie and Towners which carries a large part of the interstate load.

The most serious food supply problem in the New York area concerns Long Island. Since all rail and highway connecting bridges would be destroyed, the 7,900 tons of food per day needed by these survivors would have to be moved by water. Adequate dock facilities would exist at Port Reading, Perth Amboy, and South Amboy for the transfer of freight cars to rail barges. With the exception of a large number of small boat harbors, dock facilities on Long Island, however, would probably all be lost. Three alternative solutions to this serious logistic problem are suggested:

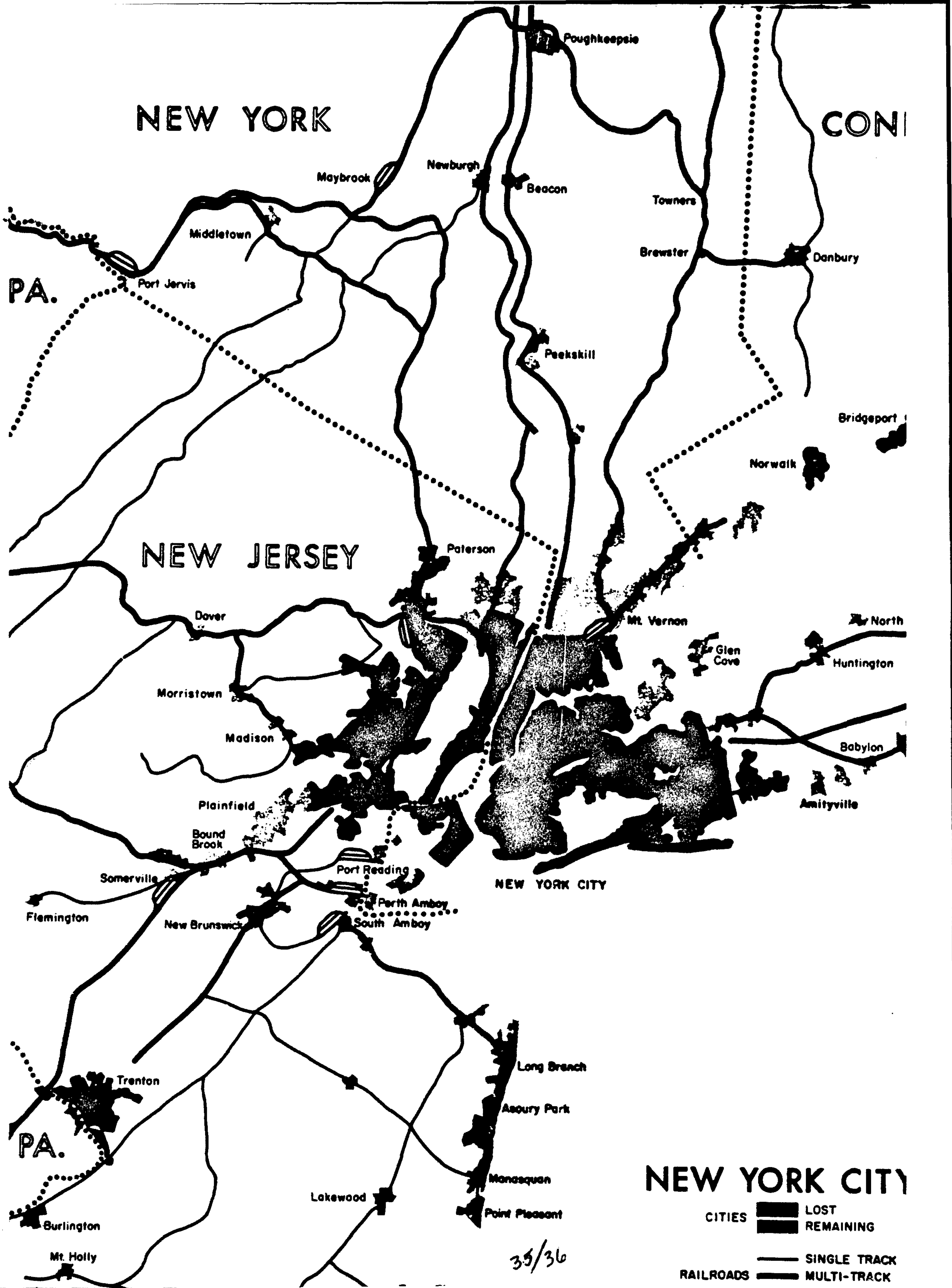
1. Special facilities for receiving rail barges could be built far out on the island.

2. A fleet of small boats could be used; however, in this event, the facilities in New Jersey might not be adequate.

3. A special transfer system might be utilized, such as bow-unloading craft similar to landing ships with special ship-mounted handling devices.

It is to be noted that each alternative requires pre-attack planning and perhaps considerable investment.

The supplying of food to survivors in the New York area, except for Long Island, could probably be accomplished with the yards and network which would survive. Fifty-five serviceable locomotive units would be needed to deliver freight cars, to spot them on sidings near groups of survivors and to remove empty cars. These would be in addition to those available in surviving yards and those engaged in interstate movement. Considerable additional planning would be necessary to meet the needs of survivors on Long Island.


NEW YORK
CONN
PA.
NEW JERSEY
PA.
Poughkeepsie
Maybrook
Newburgh
Beacon
Towners
Middletown
Brewster
Danbury
Port Jervis
Peekskill
Bridgeport
Norwalk
Paterson
Dover
Mt. Vernon
North
Glen Cove
Huntington
Morristown
Madison
Babylon
Amityville
Plainfield
Bound Brook
Somerville
Port Reading
NEW YORK CITY
Flemington
Perth Amboy
New Brunswick
South Amboy
Long Branch
Trenton
Asbury Park
Monasquan
Lakewood
Point Pleasant
Burlington
Mt. Holly
NEW YORK CITY
CITIES
LOST
REMAINING
RAILROADS
SINGLE TRACK
MULTI-TRACK

Philadelphia Rail Activity Center

Rail transportation services for the 2 million survivors in the Philadelphia rail activity center would be complicated by the weapons directed against Trenton, Easton, Reading, Harrisburg, York, Lancaster, Altoona (see Pittsburgh map), and Wilmington. The only direct rail link with New York would cross the Delaware River just 3 miles north of Trenton, and this massive stone arch bridge would have only a 53 percent chance of surviving the weapons assigned to Trenton. The surviving route to Baltimore, except for one isolated line, would pass through Holidaysburg, Pennsylvania, where a yard parallel to the main line is only 4.7 miles from the aiming point in Altoona. Although it is unlikely that the track would be cut, there might be a sizable clearing problem. The Wilmington, Baltimore, and Norfolk weapon assignments would isolate the east shore of Chesapeake Bay, requiring supply through the Philadelphia rail activity center via Coatsville and Newark.

The Philadelphia area would have no single yard which could act as a classification center for freight movement. The Rutherford automatic hump yard east of Harrisburg, which would be damaged, might be repaired to form such a focal point. H + 1 radiation of only 441 r/hr would permit early entry for repair; however, the break in the main rail lines at Harrisburg would make its location awkward. The most likely classification center consists of the 11 yards in the Bethlehem to St. Clair area which have an aggregate capacity of 15,000 cars. A workable management organization would have to be established and communication lines provided before the complex could function as a system. In the balance of the Philadelphia area there are more than 30 small yards, each of which can accommodate 200 cars or more, with an aggregate capacity of over 20,000 cars.

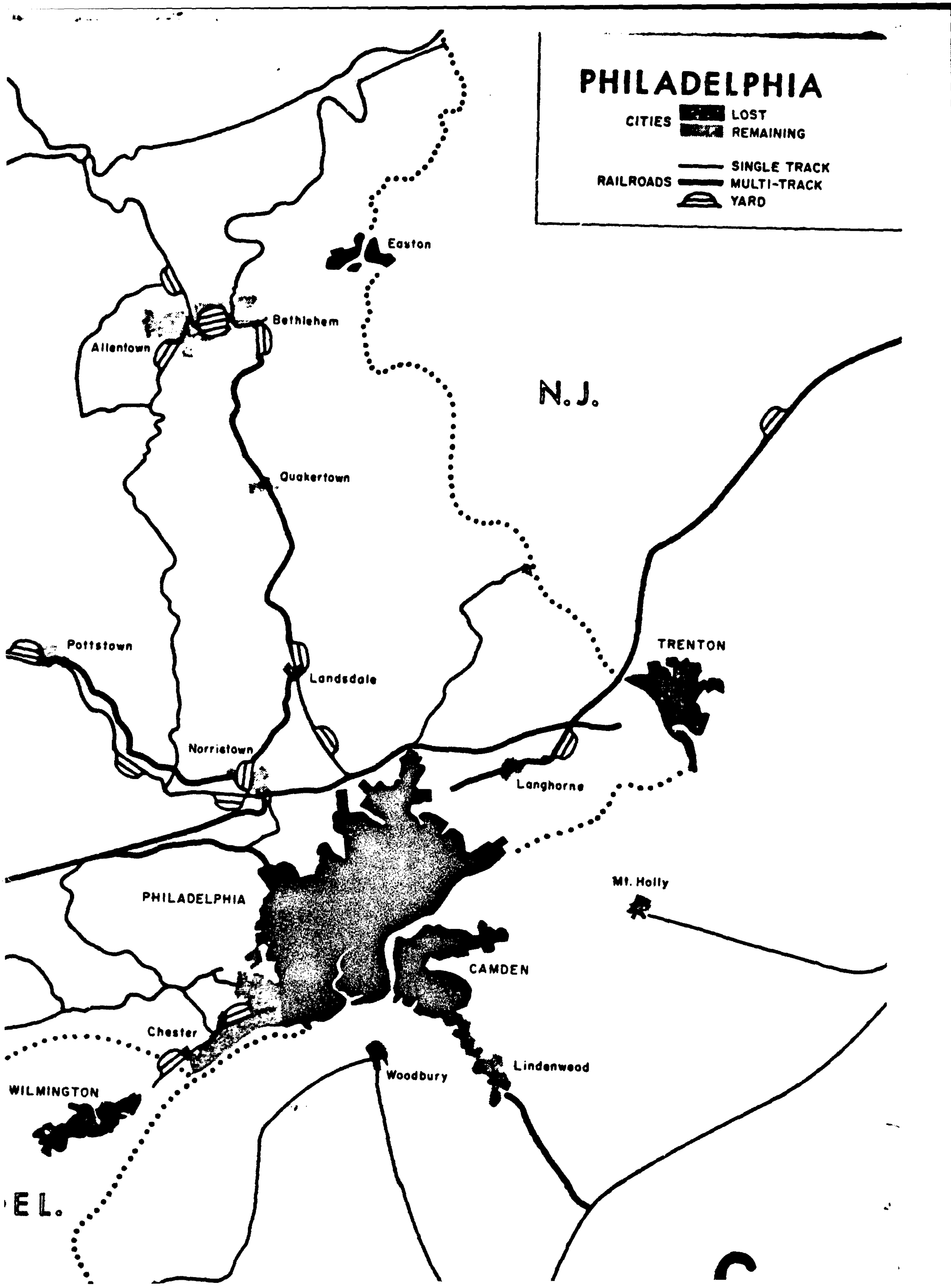
If multiple-unit trains could be used to transfer cars from the classification center to the support yards, the factor which would limit the traffic would be the rail connections to outside areas. These could handle a total of 90 trains per day, giving an indicated yard load of 3,500 cars per day. With well-coordinated operation, the yards in the switching center might handle 7,500 cars per day.

The distribution of 191 carloads of food per day to survivors throughout the Philadelphia rail activity center, including the 400,000 survivors on the east shore of Chesapeake Bay would be a 2-step movement. Multiple-unit trains would move from the classification center to small yards near the surviving population. Final delivery and switching would be performed by locomotive units stationed at these small yards. Because of the numerous targets in the area, some of the routes would be long and devious. The route from the classification center to the east shore of Chesapeake Bay would be 674 miles, round trip, and several other round-trip routes would exceed 300 miles. This food distribution service would require 35 locomotive units in addition to those available in the surviving yards.

The movement of food would represent about 10 percent of the postattack capability of yards in the classification center and 18 percent of the capability of the critical portion of the belt line between Coatsville and Norristown.


Sunbury
Tamaqua
St. Clair
Pottsville
Hamburg
PENNSYLVANIA
HARRISBURG
Lebanon
READING
Middletown
Lancaster
York
Coatsville
Quarryville
Hanover
MD.
A


Tamaqua
St. Clair
Pottsville
Allentown
Hamburg
NNSYLVANIA
Lebanon
READING
Pottstown
Norristown
Lancaster
PHILADELPHIA
Coatsville
Quarryville
Chester
WILMINGTON
Newark
DEL.


PHILADELPHIA
CITIES
LOST
REMAINING
RAILROADS
SINGLE TRACK
MULTI-TRACK
YARD
Easton
Bethlehem
Allentown
N.J.
Quakertown
Pottstown
Landsdale
TRENTON
Norristown
Langhorne
PHILADELPHIA
Mt. Holly
CAMDEN
Chester
Lindenwood
Woodbury
WILMINGTON
EL.

Baltimore Rail Activity Center

To perform the necessary rail distribution functions in the postattack period, the Baltimore rail activity center would have to be expanded to include Hagerstown in the west with its vital rail connections. It would also include the Washington, D.C., area and the west shore of Chesapeake Bay if survivors in these areas were to be supplied by rail.

Destruction of yards at both Baltimore and Washington would be essentially complete. In the Baltimore area, yards at Sparrows Point would be only damaged but they would be isolated from the rail network.

With the loss of the 14th Street Bridge, the only rail connection between Washington and the south would be severed. Even with a favorable orientation, this bridge would have only a 31 percent chance of survival without considering the heavy damage and debris likely near the bridge.

Rail service to the 800,000 survivors as well as interstate traffic would hinge on the yards in the Hagerstown-Brunswick area whose combined capacity is 10,000 cars. While this system would resemble the Philadelphia area classification complex, these yards are more favorably situated for closer coordination. These yards would have convenient connections with the single-track link to Philadelphia, the double-track to Pittsburgh, the single-track to Charleston,[1] and the two Potomac River crossings to the south. The combined capability of these interstate rail lines would be 90 trains per day corresponding to a classification load of almost 3,500 cars per day. This requirement would be less than the capability of the yards in the classification center operating with 2-day average holding time.

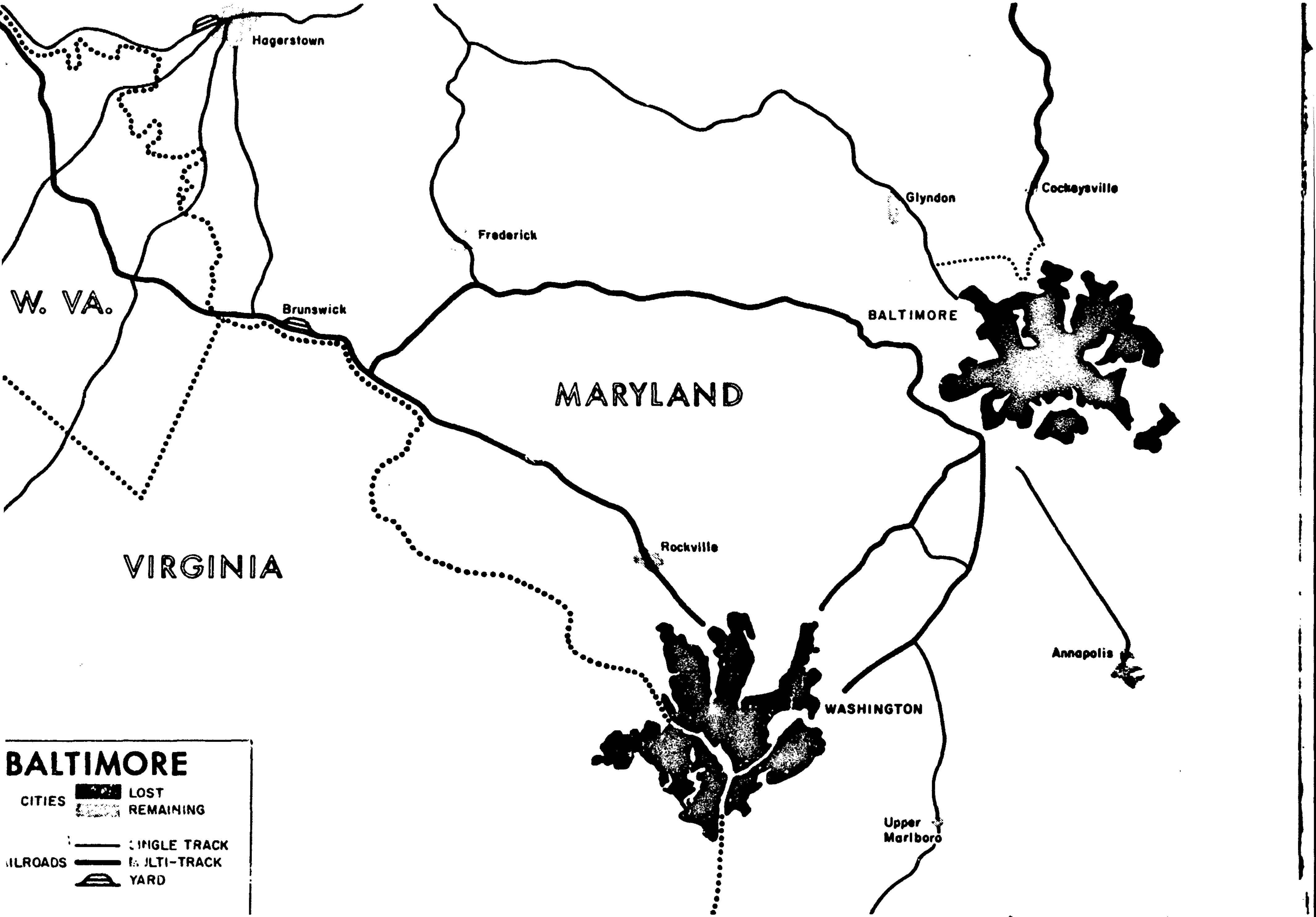
Despite the relatively low requirement of 62 carloads of food per day for the survivors, the logistic distribution problem would be significant. The connection between Hagerstown and the two rail lines between Baltimore and Washington depends upon a junction south of Baltimore close to an assigned aiming point. The probability of having the rail lines at this junction intact after the attack would be 85 percent and that of the entire loop approximately 65 percent. These optimistic probabilities do not describe the whole problem, however. Homes, buildings, pole lines, and other structures would likely have to be cleared from the track. The radioactive fallout at the junction would be approximately 1,500 r/hr, enough to delay clearance of debris for about 3 weeks.

Prior to the opening of this critical junction, the 250,000 survivors in Ann Arundel, Calvert, Charles, Prince Georges, and St. Marys counties would have to be supplied by highway from Frederick or more distant Hagerstown or by water from a point in the Philadelphia area, perhaps as far away as Chester. Highway movement of 750 tons of food per day would require a substantial fleet of trucks--perhaps 100 (making daily round trips with an average load of 10 tons) would be required to maintain this delivery rate from Frederick.

There would be only three rail lines from Hagerstown to Baltimore and Washington, two double-track and a single. These could not support the traffic of similar through routes because of terminal and switching problems. It is the capacity of support yards and freight terminals which is most likely to limit the recovery of this area.

Local food deliveries plus stepped-up yard activity would likely require 5 additional locomotive units.

1/ See Appendix B for definition of Charlestown rail activity center.


BALTIMORE
CITIES
LOST
REMAINING
ILROADS
INGLE TRACK
LTI-TRACK
YARD
Hagerstown
Frederick
Glyndon
Cockeysville
BALTIMORE
Brunswick
W. VA.
MARYLAND
VIRGINIA
Rockville
Annapolis
WASHINGTON
Upper Marlboro

Pittsburgh Rail Activity Center

In the Pittsburgh rail activity center, weapons directed against Altoona, Johnstown, Pittsburgh, and Wheeling would disturb main east-west routes as well as reducing mobility within the area.

Holidaysburg would be a key point for movement between Philadelphia and Baltimore as well as between Philadelphia and Pittsburgh. The main line passes through Holidaysburg where it could be blocked by debris. Light construction in Holidaysburg would be badly damaged by the weapon directed against Altoona, although debris from brick, wood, and metal-frame buildings is not likely to be scattered over a wide area. The Holidaysburg yard would have an 82 percent probability of avoiding destruction and a 43 percent probability of avoiding damage. There would be almost no likelihood of damaging the track outside the city.

Transportation to Philadelphia is available along two additional routes through Butler and New Castle. The rail link with Charleston and the double-track line to Hagerstown would be essentially undisturbed. Rail connections with Youngstown and Cincinnati would be available by way of Conway, although these routes would have to detour around several Ohio target areas.

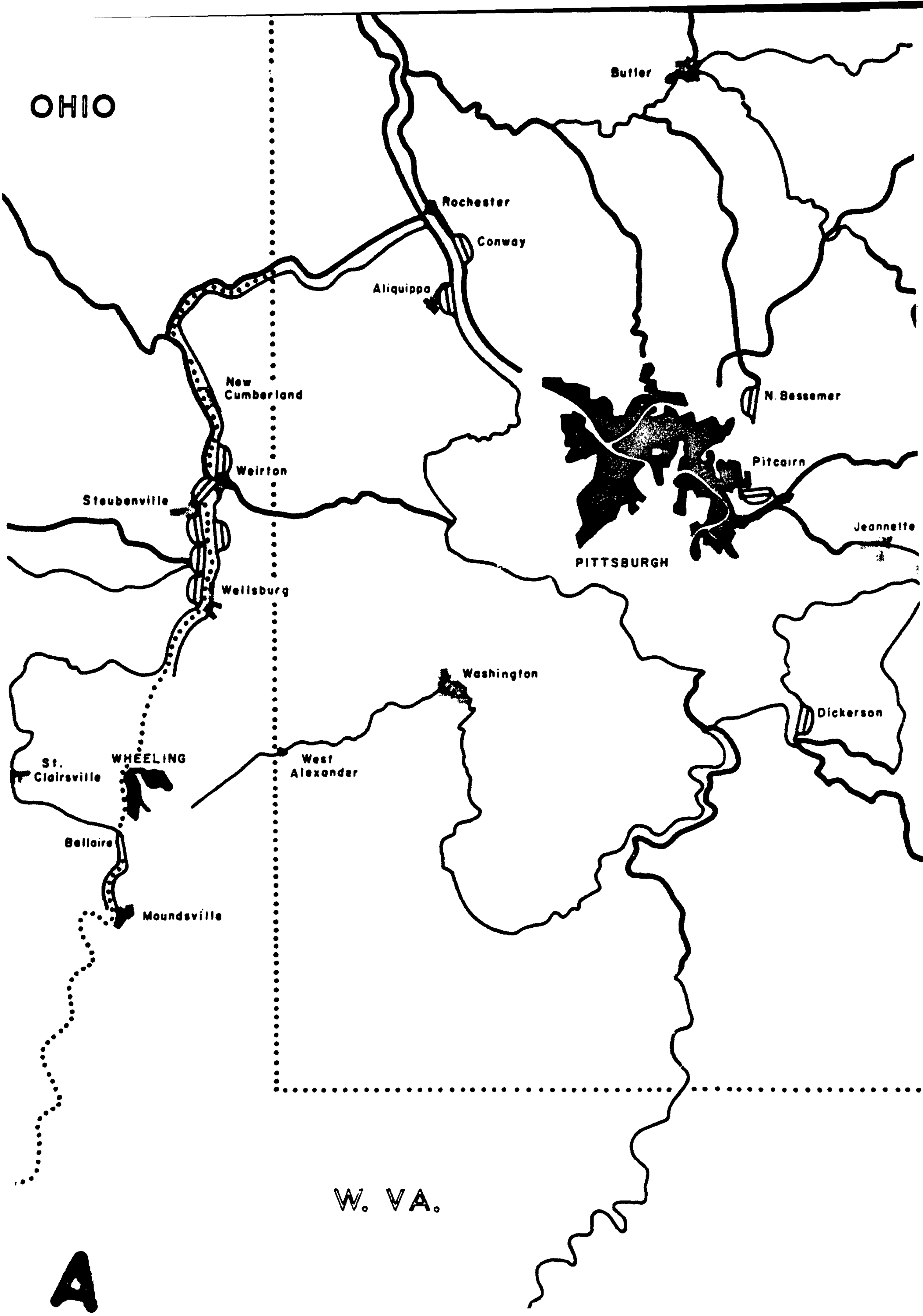
Only 9 of Pittsburgh's 44 yards would survive the attack; but one of these--Conway--could easily serve as a classification center for post-attack operations. With its capacity of 13,000 cars, it could probably handle the bulk of the interstate traffic which could move over surviving lines. Local traffic could be supported by a number of small yards.

Several large yards in different parts of the rail activity center--notably Pitcairn--would only be damaged by the attack. Fallout levels would permit repairs to begin 2 to 4 weeks following the attack.

The operation of this rail activity center is most likely to be restricted by the capability of routes around Pittsburgh. Access to Conway from both the south and east could be restricted by single-track routes--one south of Aliquippa and the other west of Butler. Additional routes involving long detours would be available north of Butler.

The distribution of 127 carloads of food per day to the 1.6 million survivors in addition to the necessary interstate movements would produce traffic equal to 40 percent of the capability of the single-track, limiting movement from Aliquippa to Dickerson. The ability to move rail freight around this area could limit the rate of recovery.

Local food distribution would require 15 serviceable locomotive units in addition to those available in surviving yards. The local and interstate food supply would utilize 19 percent of the post-attack capability of the Conway yard, based on a 2-day turnover.


OHIO
Butler
Rochester
Conway
Aliquippa
New Cumberland
N. Bessemer
Weirton
Pitcairn
Steubenville
Jeannette
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Wellsburg
Washington
Dickerson
St. Clairsville
WHEELING
West Alexander
Bellaire
Moundsville
W. VA.
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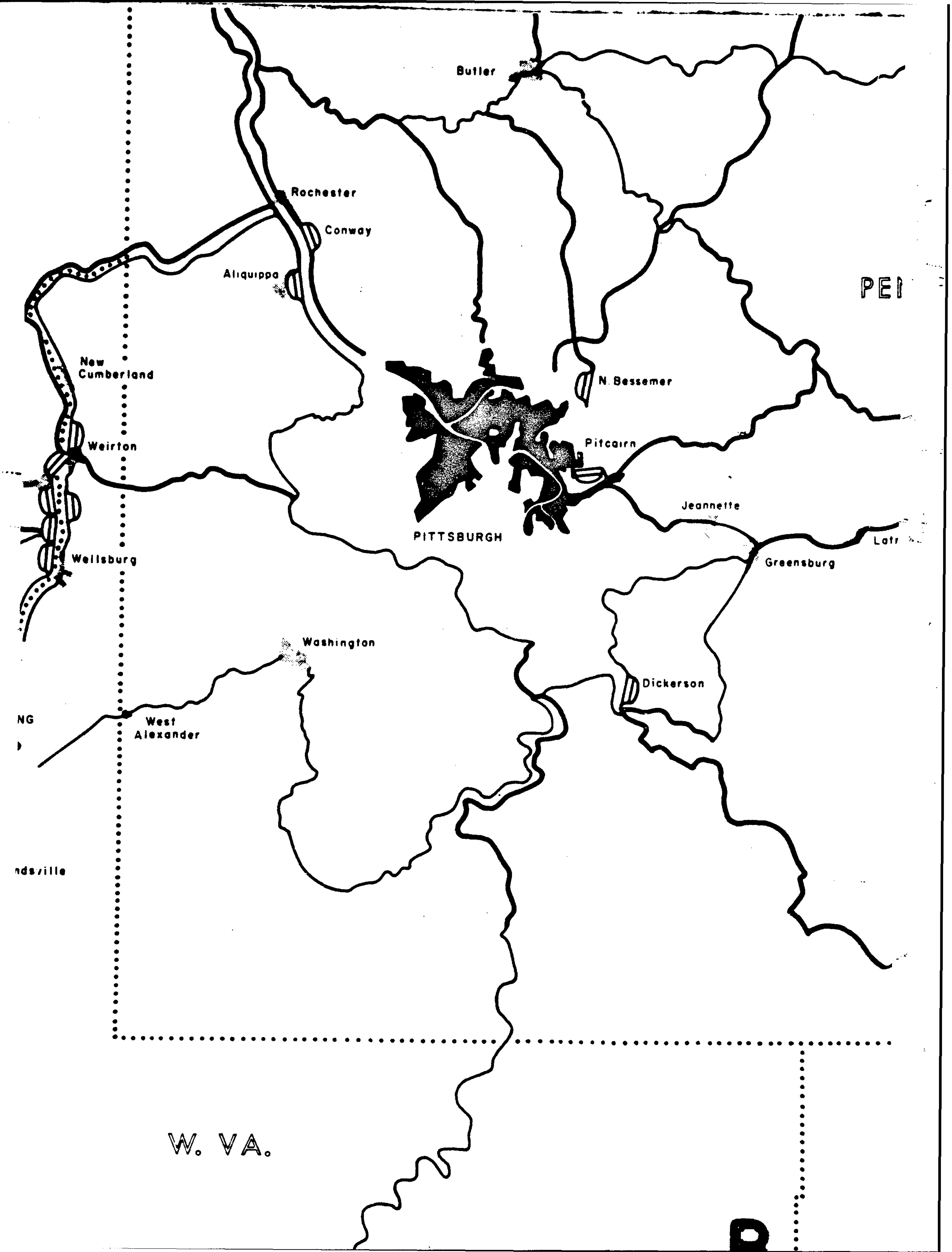
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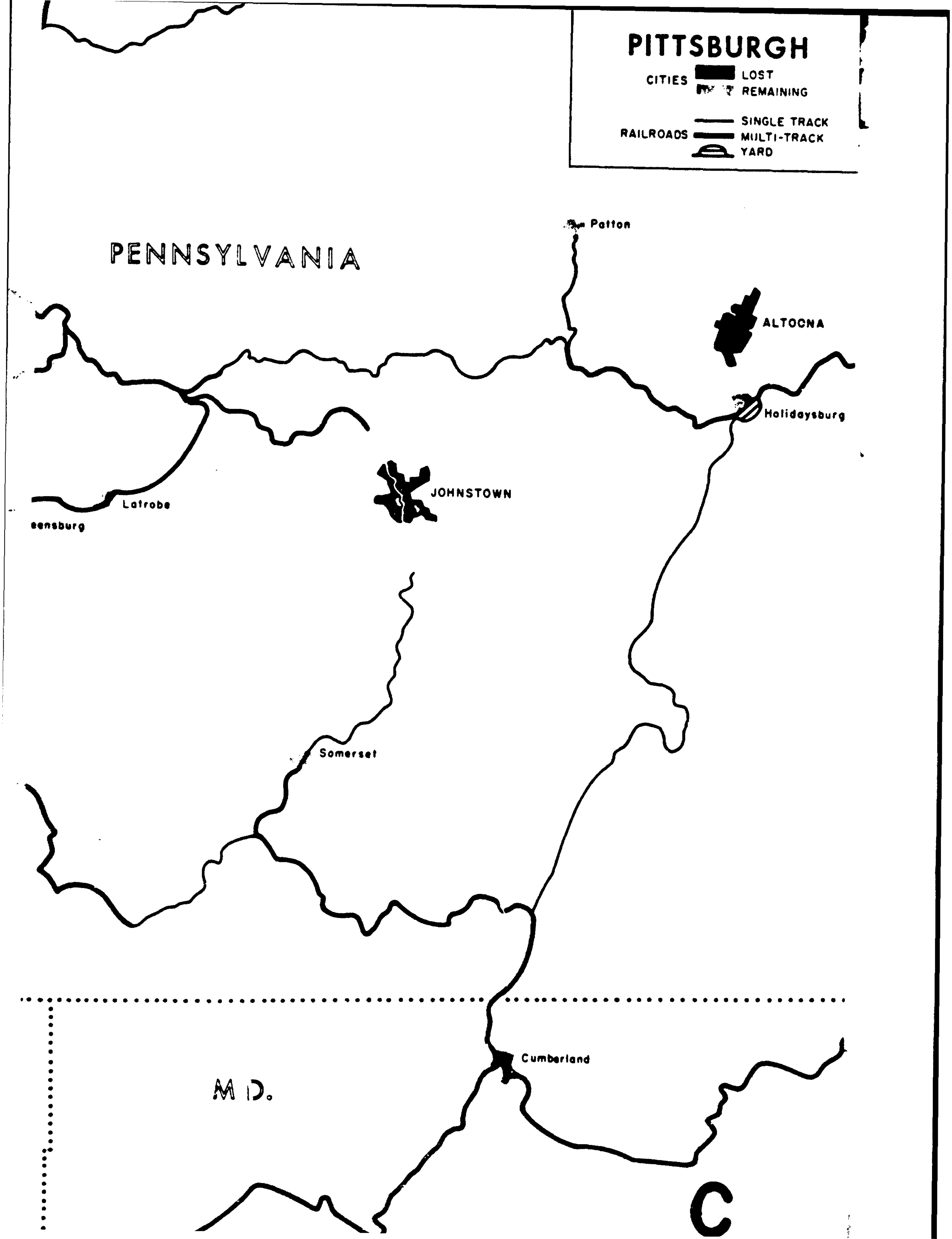
PITTSBURGH
CITIES
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RAILROADS
SINGLE TRACK
MULTI-TRACK
YARD
PENNSYLVANIA
Patton
ALTOONA
Holidaysburg
JOHNSTOWN
Latrobe
eensburg
Somerset
Cumberland
M D.
C

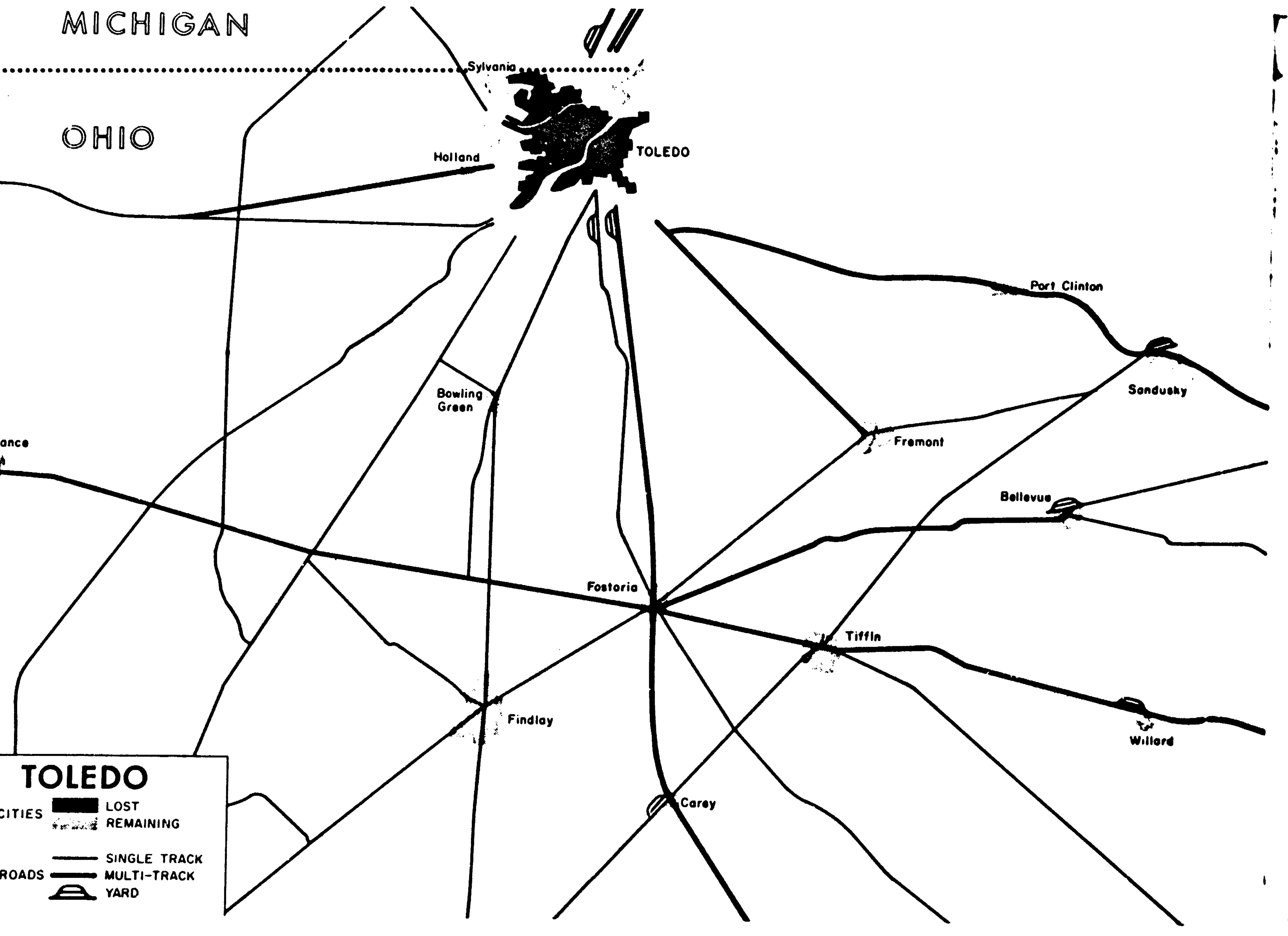
Toledo Rail Activity Center

Detailed analysis of the Toledo rail activity center reveals a shortcoming in the Resource Compendium procedure of assigning standard county locations to yards. In the Resource Compendium, two large yards south of Toledo were assigned to a standard location for Wood County. Since this point would be subjected to an overpressure of 10 psi, the yards were listed as destroyed. A careful check indicated that the yards are, in fact, 4.5 miles from this standard location and have an 86 percent probability of avoiding damage. Thus, the statistical tabulation of surviving rail facilities has been altered. In actual operation, however, these yards would be less valuable than their 15,000-car capacity would indicate. Both would be located at the end of stub tracks (whose through connections would be blocked by blast damage) and hence would be best suited for marshaling freight destined to nearby points.

Although rail links connecting Toledo to other rail activity centers would abound in detours, capability in excess of survival requirements appears available. There are at least 4 first-class lines connecting Toledo and Cleveland, although these are considerably restricted at the Cleveland end. Two alternative routes are available to Charlestown. Single-track connections remain with Cincinnati and St. Louis, and two double tracks and a single track provide links with Chicago. Because of restrictions elsewhere, it is unlikely that these lines would reach their capability of 225 trains per day. If they did, however, the surviving yards in the Toledo area could probably handle the load, even with an average holding time of 2 days.

The principal classification activities for post-attack Toledo would probably be centered in one or more of the large surviving yards south and east of the rail activity center. The yard at Willard, for example, has a capacity of 5,900 cars. The classification of 1,000 freight cars of food per day in interstate movement plus the 24 carloads needed for local delivery to feed the 300,000 survivors, could easily be accomplished in this yard. Additional yards at Sandusky, Bellevue, Carey, and other points, which have an aggregate capacity of 20,000 cars, could handle a high volume of construction supplies for rebuilding Toledo.

With the small food requirements, and a reasonably convenient belt line around the damaged area, it is likely that survival food could be delivered with 3 locomotive units in addition to those which would be available in surviving yards.


MICHIGAN
OHIO
Sylvania
TOLEDO
Holland
Bowling Green
ance
Port Clinton
Sandusky
Fremont
Bellevue
Fostoria
Tiffin
Findlay
Willard
Carey
TOLEDO
CITIES
LOST
REMAINING
ROADS
SINGLE TRACK
MULTI-TRACK
YARD

Chicago Rail Activity Center

The Chicago area would suffer heavy casualties to population, industry, and rail facilities. Over 5 million people would be blast and fallout victims. Damage to the steel, oil, power, and other industries along the shores of Lake Michigan would be extensive. Of the 167 railroad yards in the area, 100 would be destroyed and 41 damaged.

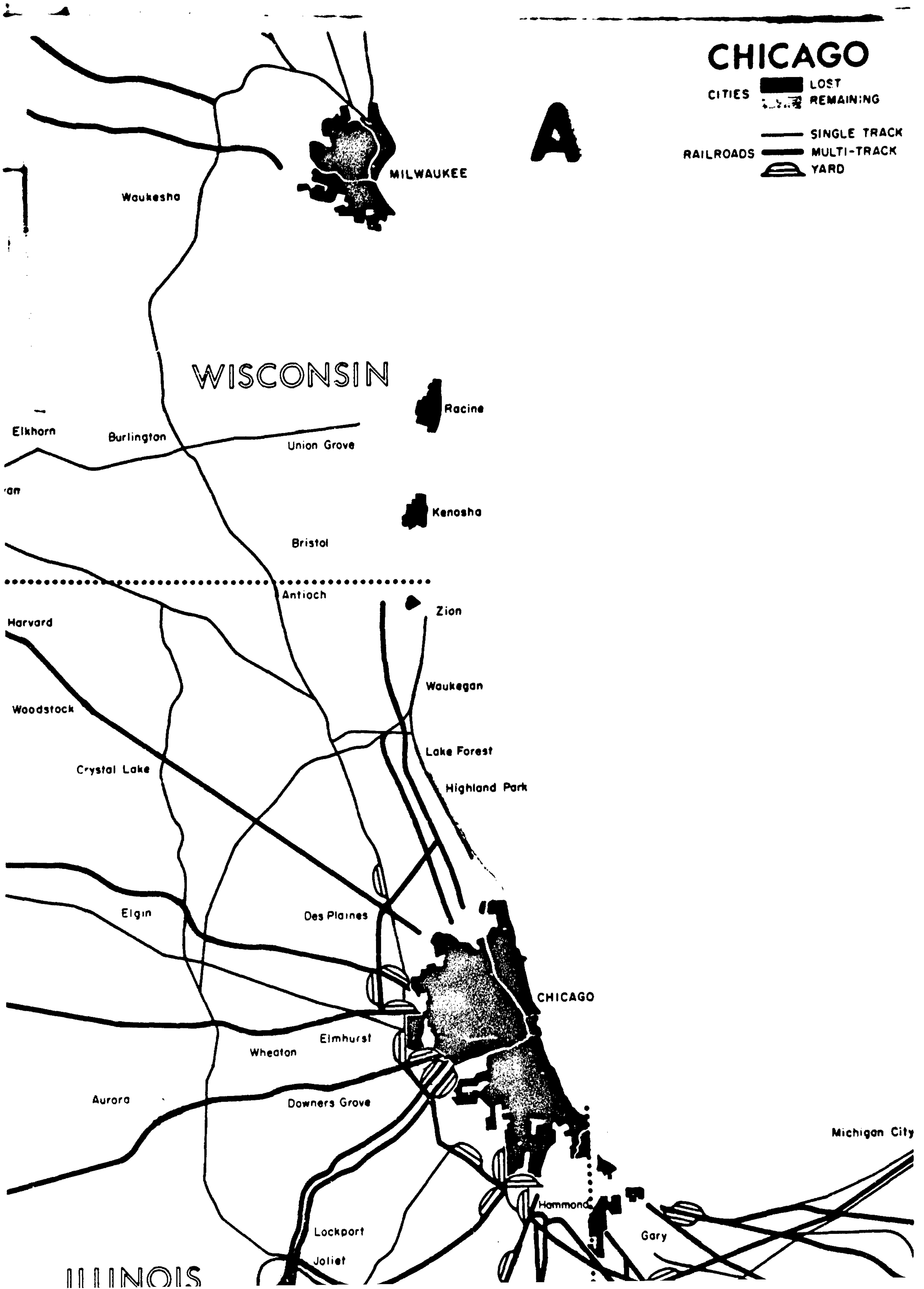
Despite this heavy loss of life and material, post-attack Chicago would probably hold leadership in the railroad industry because of its extensive surviving facilities for transfer and interchange of traffic between east and west. Chicago would retain a double belt line connecting all rail lines coming into the area. The first, a double-track line, would be close to the damaged area, providing, in conjunction with radial lines, easy access to survivors. To the north, this line would terminate at Highland Park where it would join the north shore lines. The outer belt line through Joliet and Elgin would also go around Milwaukee. North of Milwaukee, this rail line would pass within 5 miles of a weapon point of aim. The tracks would be exposed to an overpressure of approximately 5 psi, with an 84 percent probability that the line would survive undamaged. The survival of this line is important since its loss would necessitate long detours to reach Marquette and Duluth.[1/]

1/ See Appendix B for definition of the Marquette and Duluth rail activity centers.

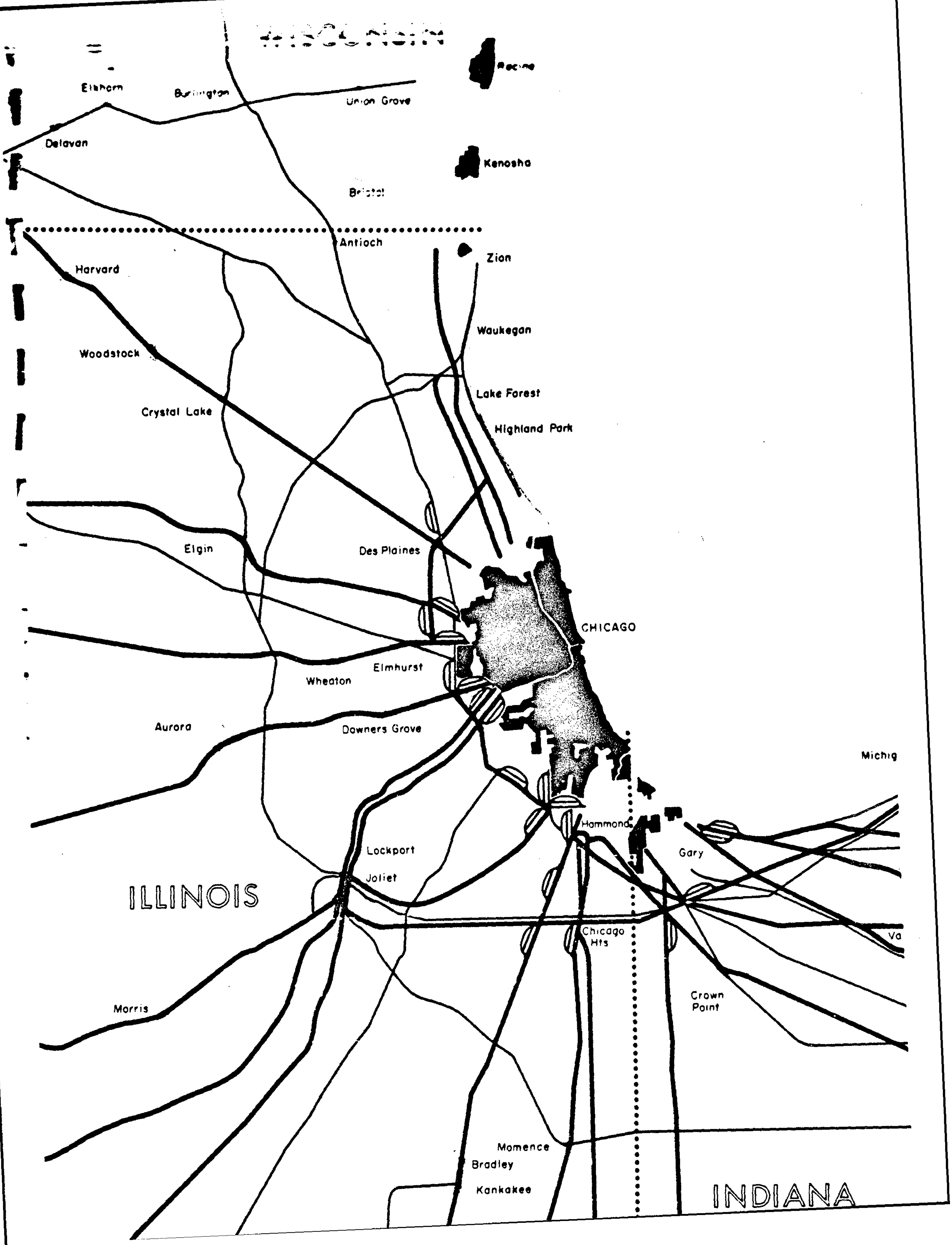
The 26 railroad yards which would survive the attack have a capacity of 57,000 cars. Because Chicago's interstate classification load of 4,710 cars per day would be large compared with 187 per day for local delivery to the 2.4 million survivors, the majority of these yards would have to be incorporated in the classification center. Most of them are clustered near the inner belt line making such an arrangement feasible; however, good management and adequate communications would be essential.

The lines connecting Chicago with other rail activity centers would have an aggregate capability of 450 trains per day giving an indicated classification load of 17,000 cars per day. With an average holding time of 2 days, the surviving classification yards could handle 25,000 cars per day. In order to carry this volume of traffic, very close coordination among all surviving yards would be needed and, in addition, traffic on the two available belt lines would have to be closely regulated. The establishment of reliable communications together with effective management of all surviving facilities in the area might permit this level of traffic to be reached.

Delivery of 187 carloads of food to sidings near surviving communities would require the services of 15 locomotive units in addition to those in the surviving yards. Delivery sidings are not likely to be a problem in the immediate vicinity of Chicago, although they might be in short supply in the area between Chicago and Milwaukee.



CHICAGO
CITIES
LOST
REMAINING
RAILROADS
SINGLE TRACK
MULTI-TRACK
YARD
A
MILWAUKEE
Waukesha
WISCONSIN
Racine
Elkhorn
Burlington
Union Grove
Kenosha
Bristol
Antioch
Zion
Harvard
Waukegan
Woodstock
Lake Forest
Crystal Lake
Highland Park
Elgin
Des Plaines
CHICAGO
Elmhurst
Wheaton
Aurora
Downers Grove
Michigan City
Hammond
Gary
Lockport
Joliet
ILLINOIS



Racine
Elkhorn
Union Grove
Delavan
Kenosha
Antioch
Zion
Harvard
Waukegan
Woodstock
Lake Forest
Crystal Lake
Highland Park
Elgin
Des Plaines
CHICAGO
Elmhurst
Wheaton
Aurora
Downers Grove
Michig
Hammond
Gary
Lockport
Joliet
ILLINOIS
Chicago Hts
Va
Crown Point
Morris
Momence
Bradley
Kankakee
INDIANA

Minneapolis Rail Activity Center

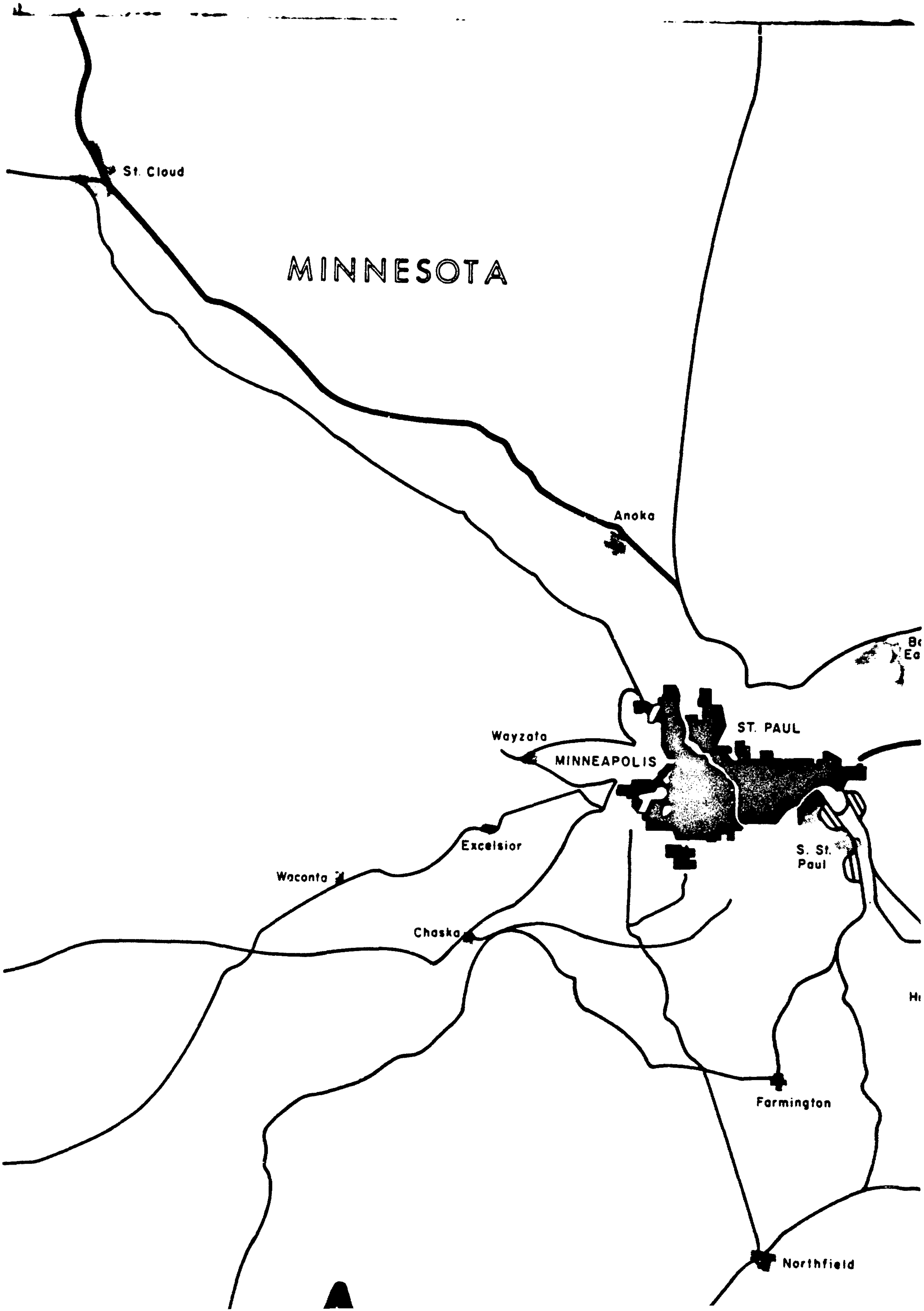
Damage to the Minneapolis-St. Paul area would be concentrated in the cities with little effect on the surrounding area. The main rail lines linking Minneapolis with other rail activity centers would remain intact outside the belt line surrounding the damaged area. Considering difficulties in signaling and communications, these lines could probably handle 165 trains per day, representing an interstate classification load of 6,200 cars per day. As might be expected, the movement of food would represent a major part of the post-attack rail traffic in Minnesota, the Dakotas, and Montana. Grain from storage in this area would move through Minneapolis to meet the large demands in the east. The interstate and local rail traffic to supply food for survival has been estimated at 1,340 loaded and empty cars or about 18 trains per day in and out of the Minneapolis area. This represents about 40 percent of the capability of the northern portion of the belt line.

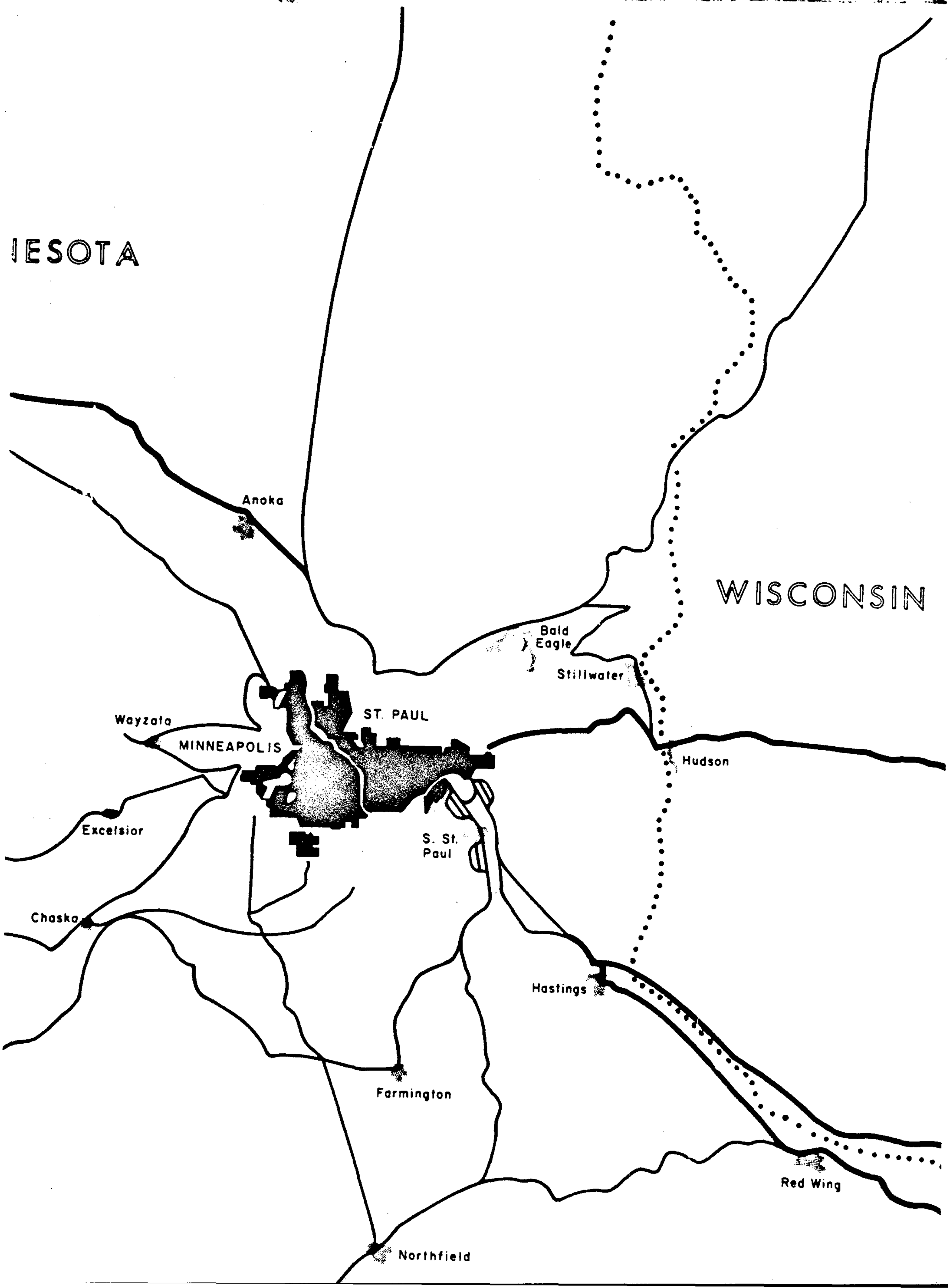
The surviving yards within the Minneapolis rail activity center which have a capacity of 6,000 cars are all located in the South St. Paul area. Rail connections from this point to the south and east are good, but those with the north and west involve long detours. This situation differs from that anticipated in the initial study. In assigning UTM coordinates to the yards in the Resource Compendium, the six Great Northern yards in Minneapolis-St. Paul were combined and given a single coordinate. Coordinates for the individual yards are listed in classified Appendix D.

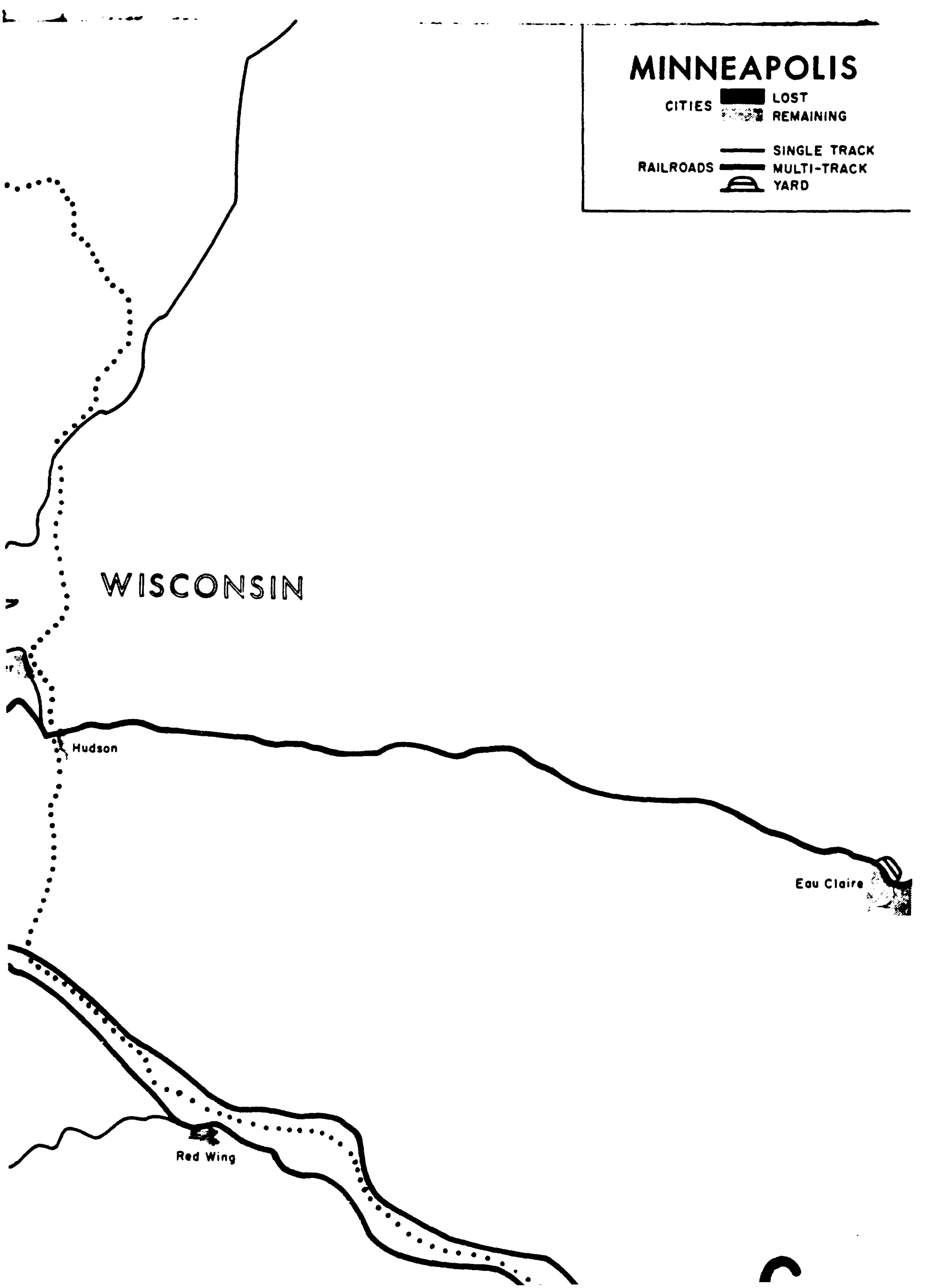
In addition to the surviving yards in South St. Paul, there are moderate-sized yards at Glenwood and Willmar, Minnesota, and Altoona, Wisconsin.[1/] Although these yards are widely separated, they represent the most logical classification center. Here, the necessity for parallel operation would outweigh the accompanying inefficiency due to shorter trains and poor equipment utilization. Effective communications and good planning and scheduling would be essential to avoid overloading the belt line which connects them. Because of the distances involved, some 18 additional locomotive units would be needed to move interstate food from one yard to another.

The delivery of food to the 650,000 survivors in the Minneapolis-St. Paul area would not be a serious problem. The 50 carloads per day requirement could be dispatched from the principal supporting yards in South St. Paul. Both loaded and empty cars could be spotted and picked up with 6 additional locomotive units.

1/ These yards do not appear on the map because of their distance from Minneapolis-St. Paul. Glenwood is 121 miles northwest of Minneapolis, Willmar is 105 miles west of Minneapolis, and Altoona is 90 miles east of St. Paul.


MINNESOTA
St. Cloud
Anoka
Wayzata
MINNEAPOLIS
ST. PAUL
Excelsior
Waconta
S. St. Paul
Chaska
Farmington
Northfield


IESOTA
Anoka
WISCONSIN
Bald
Eagle
Stillwater
ST. PAUL
Wayzata
MINNEAPOLIS
Hudson
Excelsior
S. St.
Paul
Chaska
Hastings
Farmington
Red Wing
Northfield

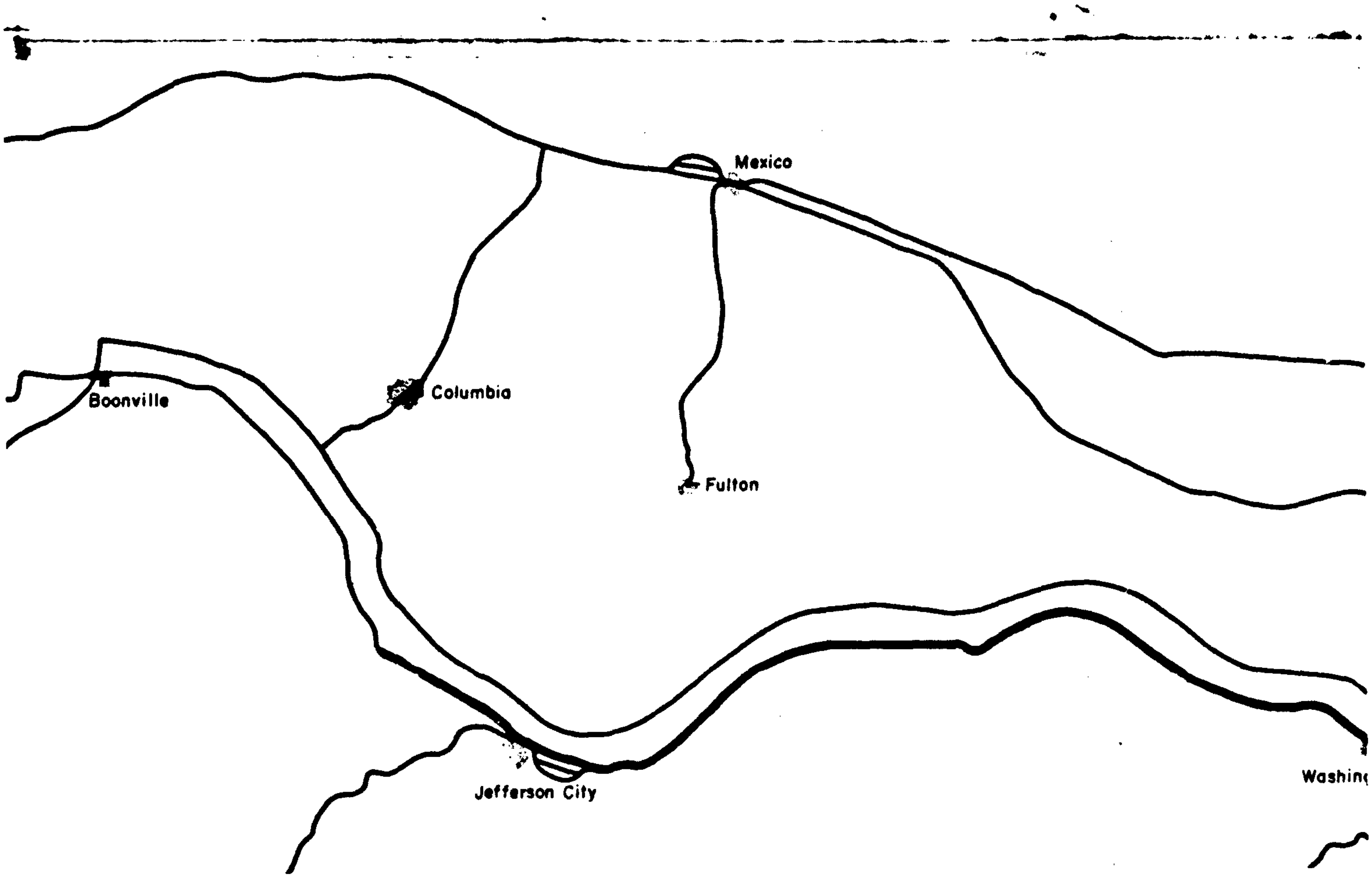

MINNEAPOLIS
CITIES
LOST
REMAINING
RAILROADS
SINGLE TRACK
MULTI-TRACK
YARD
WISCONSIN
Hudson
Eau Claire
Red Wing

St. Louis Rail Activity Center

Rail operation in post-attack St. Louis would be extremely difficult. The extensive system of yards with an aggregate capacity of 60,000 cars, along both sides of the Mississippi River, would be lost. Within the rail activity center, only two small yards at Mitchell with a 1,330-car capacity would survive. The 5,100-car yard at Dupo would have a 79 percent probability of surviving destruction, but only a 31 percent probability of avoiding damage. In view of its low H + 1 fallout intensity of 900 r/hr, this yard might be repaired and placed in operation shortly after the attack.

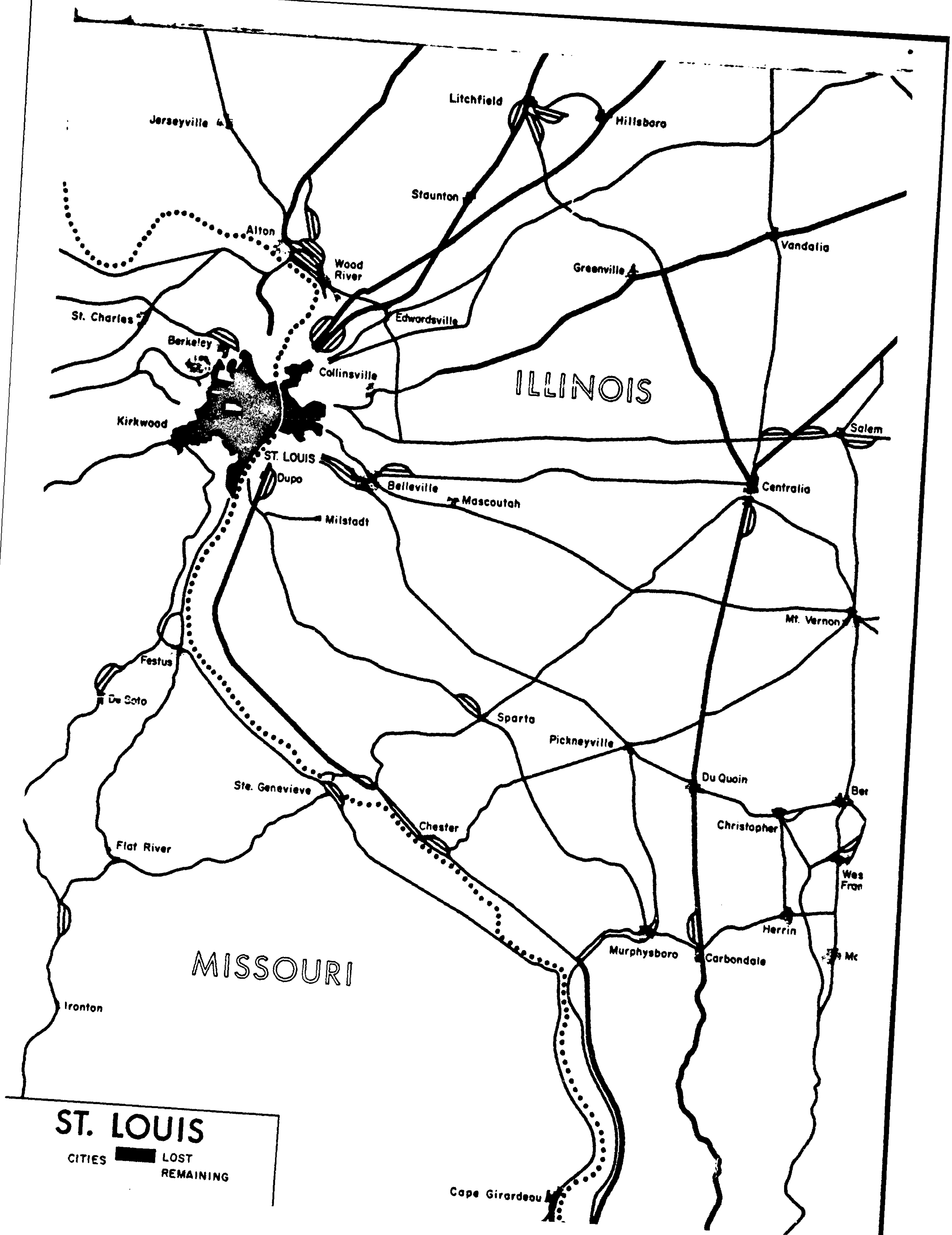
The classification load would fall on yards outside the St. Louis rail activity center. The most likely center for this activity would be southern Illinois where yards at Centralia have a capacity of 4,400 cars, Bluford, 2,000 cars, and other yards an additional 6,000 cars. It must be remembered that most of these yards now serve the coal mining area, and are not likely to be well adapted to general classification. In addition to these yards, there are a variety of small yards scattered about the area.

The closest rail line around St. Louis can hardly be called a belt line since it extends west to Boonville and south to Illmo. It is likely that north-south traffic would pass through Illinois and east-west traffic would cross the Mississippi at Alton, having been classified at Centralia, or farther north at Mattoon, Illinois. To avoid a detour through Springfield, Missouri, the belt line must pass close to points of aim at Kirkwood, Missouri. The area around this single-track crossover has been carefully inspected. The houses are far apart and the timber light. Except for a cement plant near one junction, there seems little likelihood of debris blocking the track. The cement plant is favorably located with respect to the track so that its debris would be scattered in another direction. The probability of the track surviving would be 94 percent. While the turnouts to connecting lines are not especially convenient, they could be used.



Delivery of 52 carloads of food per day to the 700,000 survivors near St. Louis plus an additional 26 carloads to the 350,000 survivors in the surrounding counties would require careful coordination. Trainloads of food could be dispatched from the southern Illinois classification center to small support yards near the survivors. Final delivery could be made in a manner similar to that planned for other rail activity centers. This distribution would require an additional 15 locomotive units and at least a like number to work in the small yards where none are now stationed.

Transportation of food for survival would impose a classification load of 1,280 cars per day plus an additional local load of 78 cars per day amounting to 22 percent of the capability of the classification center. This traffic would represent 66 percent of the capability of the single-track bridge crossing the Mississippi at Alton.



Litchfield
Jerseyville
Hillsboro
Staunton
Alton
Vandalia
Wood River
Greenville
St. Charles
Edwardsville
Berkeley
Collinsville
ILLINOIS
Kirkwood
Salem
ST. LOUIS
Dupo
Belleville
Centralia
Mascoutah
Milstadt
Mt. Vernon
Festus
De Soto
Sparta
Pickneyville
Du Quoin
Ste. Genevieve
Chester
Christopher
Flat River
Herrin
Murphysboro
Carbondale
MISSOURI
Ironton
Cape Girardeau
ST. LOUIS
CITIES
LOST
REMAINING

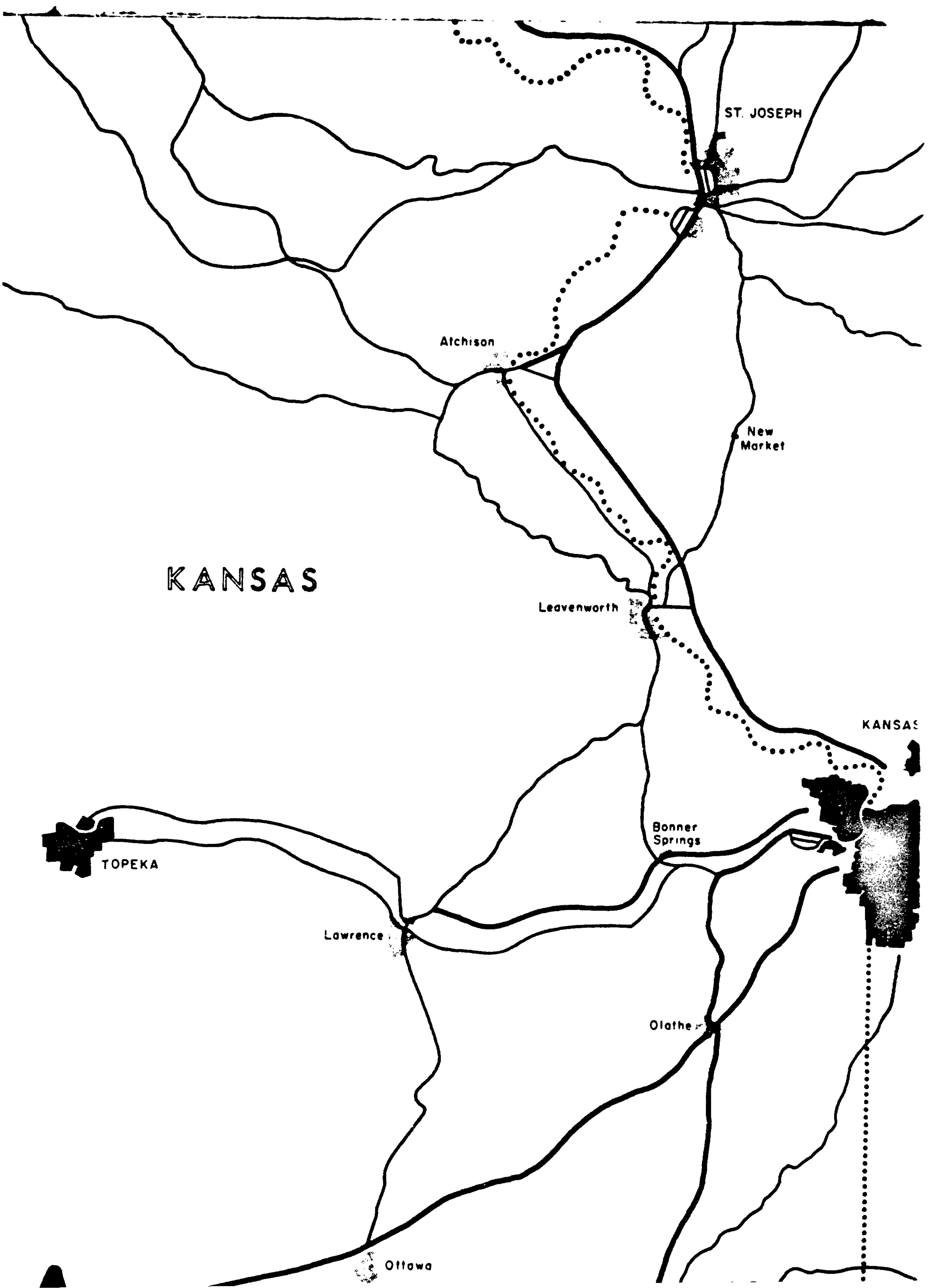
Kansas City Rail Activity Center

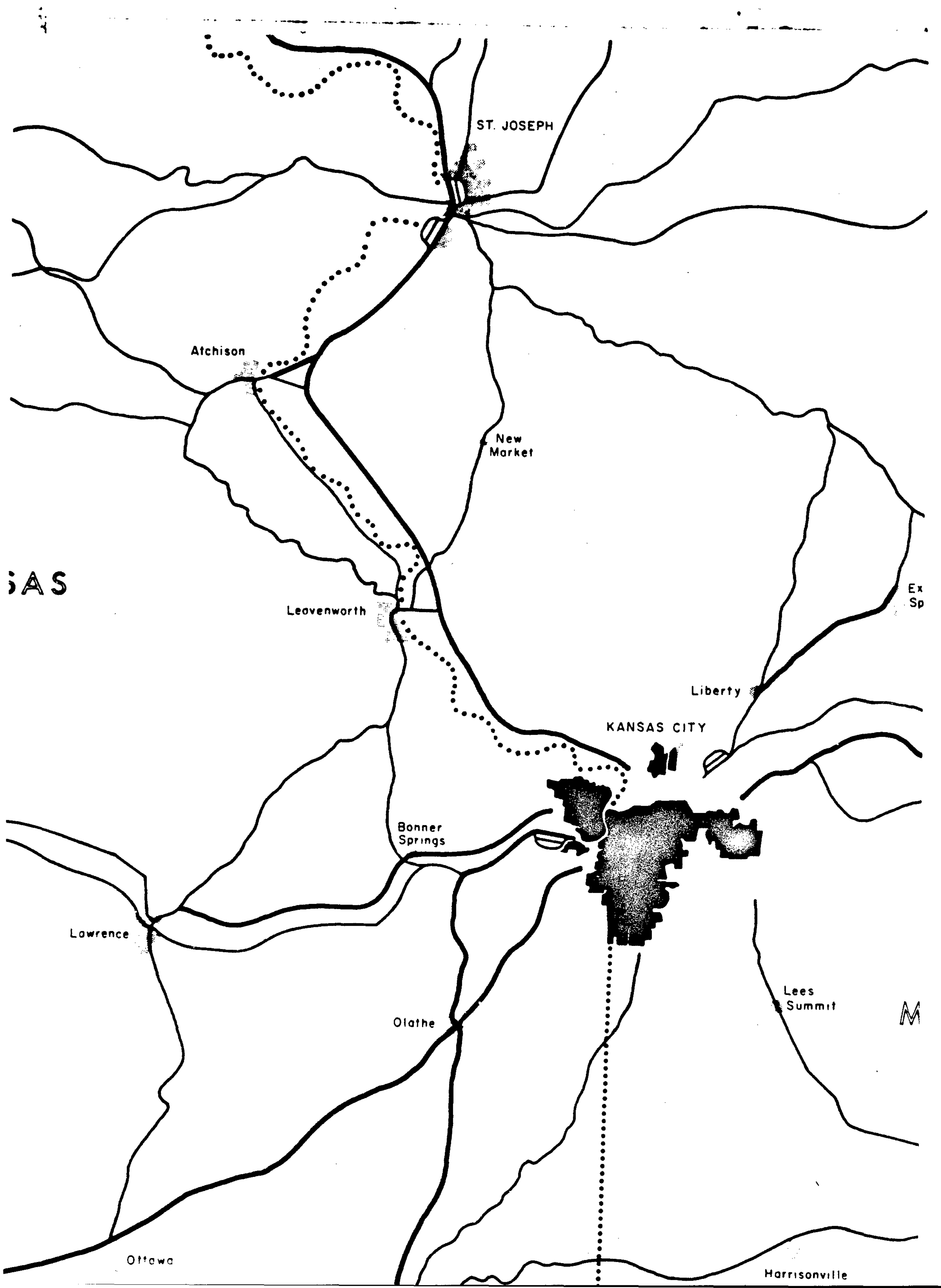
In the proposed attack, Kansas City would be effectively destroyed as a rail terminal. Along the river fronts the large yards, whose aggregate capacity exceeds 50,000 cars, would be destroyed or damaged. This destruction need not, however, block the movement of through traffic since an adequate belt line would exist. To avoid overloading this belt line, the bulk of the traffic could move through St. Joseph, Missouri.

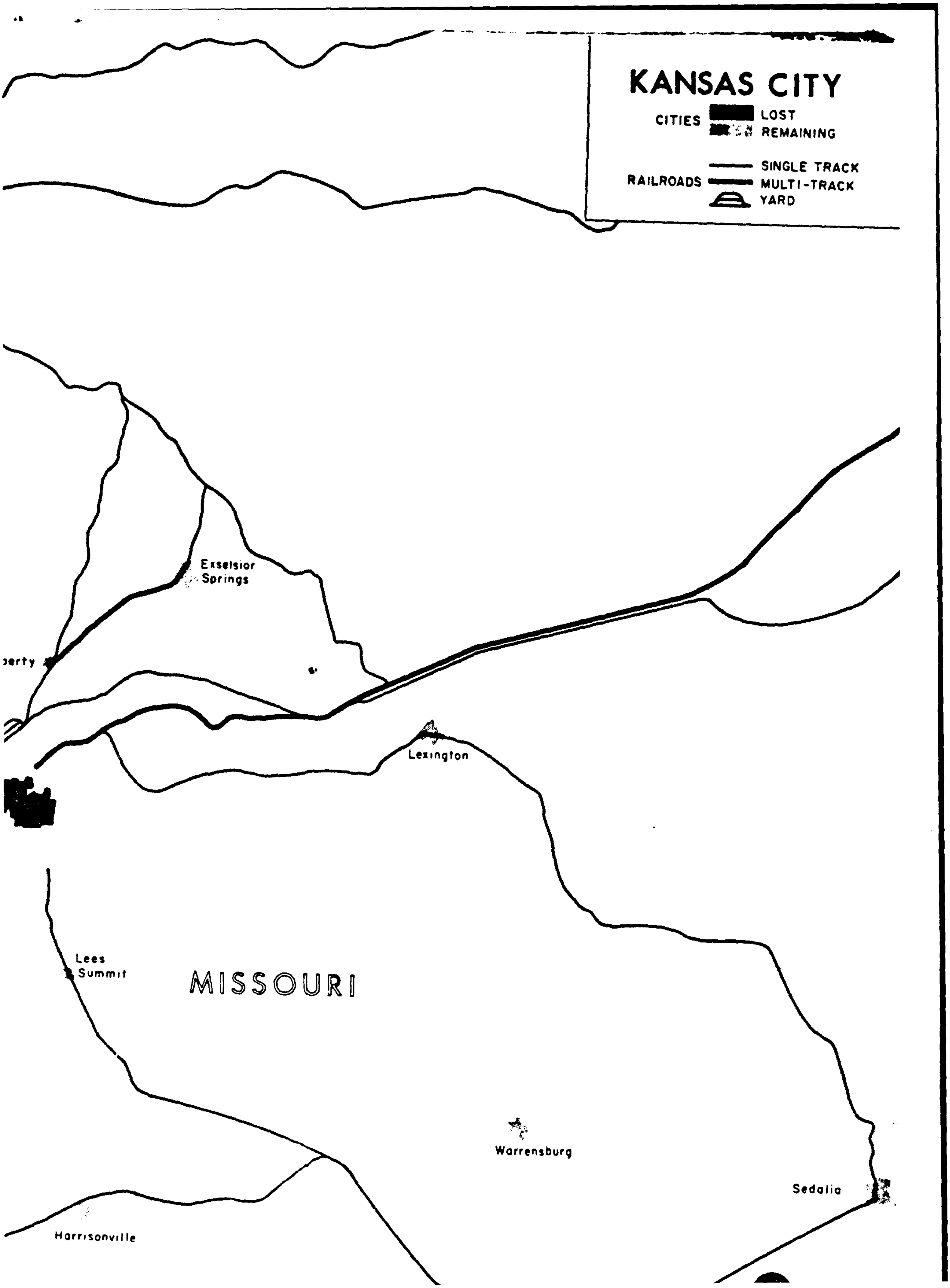
It is of interest to note that the Argentine yard located west of Kansas City, Kansas, would be undamaged if all of the assigned weapons detonated at their points of aim. When considering delivery errors of the several assigned weapons, however, the probability that this yard would escape damage is reduced to 40 percent. Nonetheless, it is favorably oriented with respect to the assigned aiming points and might therefore escape serious damage. It is unlikely that blast overpressures would be great enough to destroy an adjacent grain elevator. The support services of this yard with its 6,000-car capacity could be a great asset in rebuilding Kansas City.

St. Joseph has a total of 6 single- and 2 double-track lines connecting it with the external rail network. These could handle a maximum of 180 trains per day which compares favorably with the 285-trains-per-day capability of the main lines linking Kansas City to other rail activity centers. St. Joseph does not, however, have the necessary yard capacity to classify this level of traffic. Of those available, the large Florence yard has a capacity of 3,360 cars and is centrally located to coordinate use of the other available switching tracks. These tracks, including those serving the stockyards, could accommodate an additional 3,000 cars. The capability of the combined facilities in St. Joseph which could classify 3,200 cars per day based on a 2-day turnover does not compare favorably with the 7,300-car-per-day load which could be imposed by the network.

While the survival food load could be handled in St. Joseph, the 2,390 cars per day of interstate traffic plus the 46 cars per day needed to supply the area's 600,000 survivors would approach the capability of the St. Joseph facilities. Since long-distance movements en route would constitute a large portion of this traffic, the 2-day holding time might be reduced by passing some through traffic without classification. Distribution of the local requirements around the rail activity center would require 5 additional locomotive units. Fully coordinated operation of all St. Joseph yard facilities would require at least 5 more. The combined food traffic would represent 33 percent of the capability of the most heavily loaded survivor supply line between Leavenworth and Bonner Springs.


ST. JOSEPH
Atchison
New Market
KANSAS
Leavenworth
KANSAS
Bonner Springs
TOPEKA
Lawrence
Olathe
Ottawa


ST. JOSEPH
Atchison
New Market
SAS
Leavenworth
Liberty
Ex
Sp
KANSAS CITY
Bonner Springs
Lawrence
Olathe
Lees Summit
M
Ottawa
Harrisonville


KANSAS CITY
CITIES
LOST
REMAINING
RAILROADS
SINGLE TRACK
MULTI-TRACK
YARD
Exselsior Springs
erty
Lexington
Lees Summit
MISSOURI
Warrensburg
Sedalia
Harrisonville

Houston Rail Activity Center

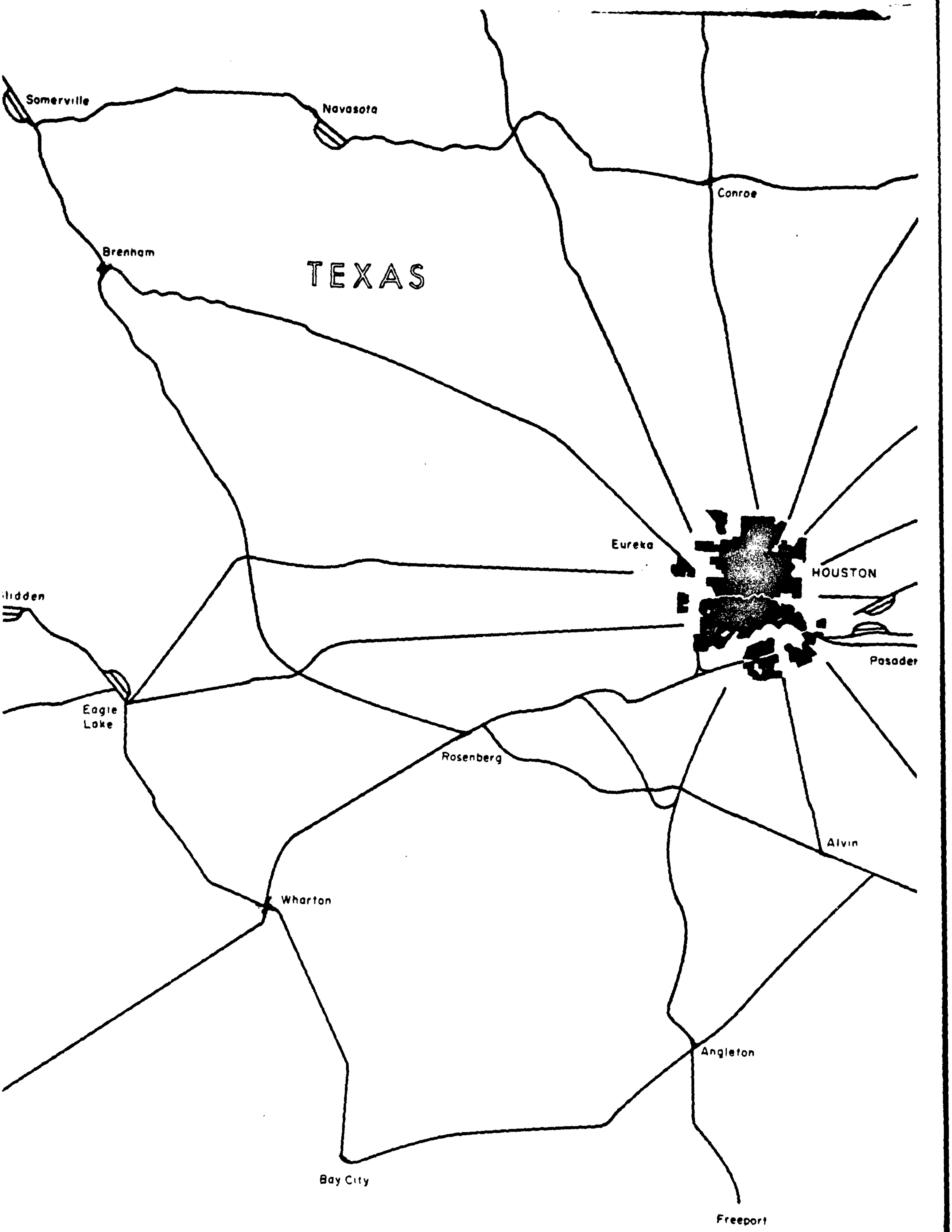
The most likely post-attack classification center for the Houston rail activity center would be Beaumont. Rail connections would be available to surviving areas; in fact, the belt line around Houston would be reasonably direct in view of the long distance between Houston and Beaumont.

The yards in Beaumont could easily handle the food requirements of the 800,000 survivors in the Houston rail activity center. The 10 trains per day would not tax the four single-track lines connecting Beaumont with the rest of the network, nor would the classification load of 740 cars per day burden these yards with their capacity of 3,220 cars. For local distribution, multiple-unit trains could be dispatched from Beaumont to 18 small support yards in surviving areas. The need for coordinated operation is evident by comparing the long-haul rail line capability of 105 trains per day operating between Houston and other rail activity centers with the 60-train-per-day capability of the 4 lines into Beaumont and the 3,220-car capability of the yards.

The yards in the Navasota-Somerville area are of particular interest because of their capacity--6,600 cars--and their proximity to each other. This group might form a better classification center than Beaumont if suitable communications and controls could be established. Although farther than Beaumont from Houston, there are 8 rail connections with the outside network. It is conceivable that the classification load could be shared by the two centers.

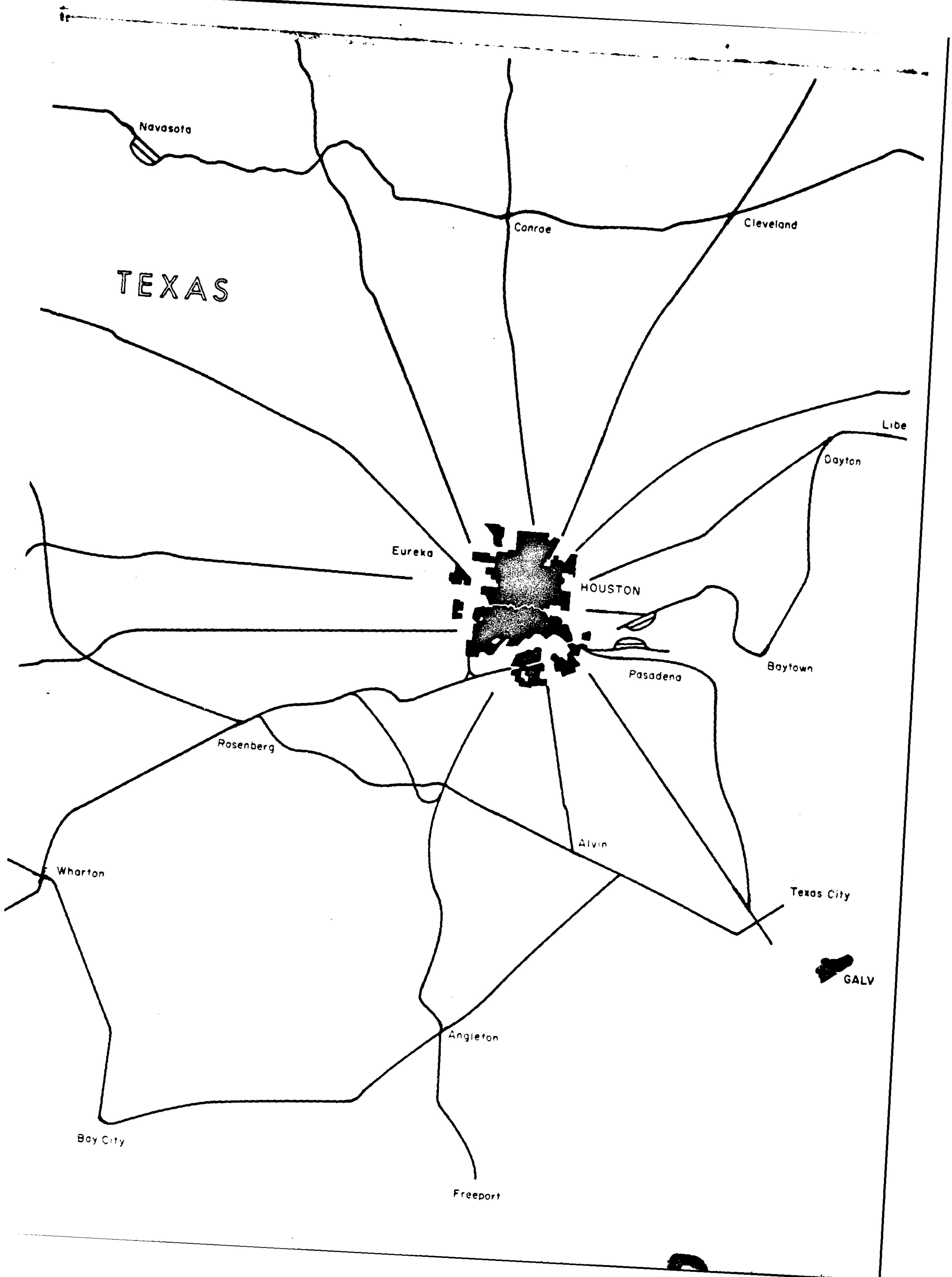
Distribution of 60 carloads of survival food per day would require 10 additional locomotive units as well as a comparable number to serve the small yards not now assigned switching locomotives.

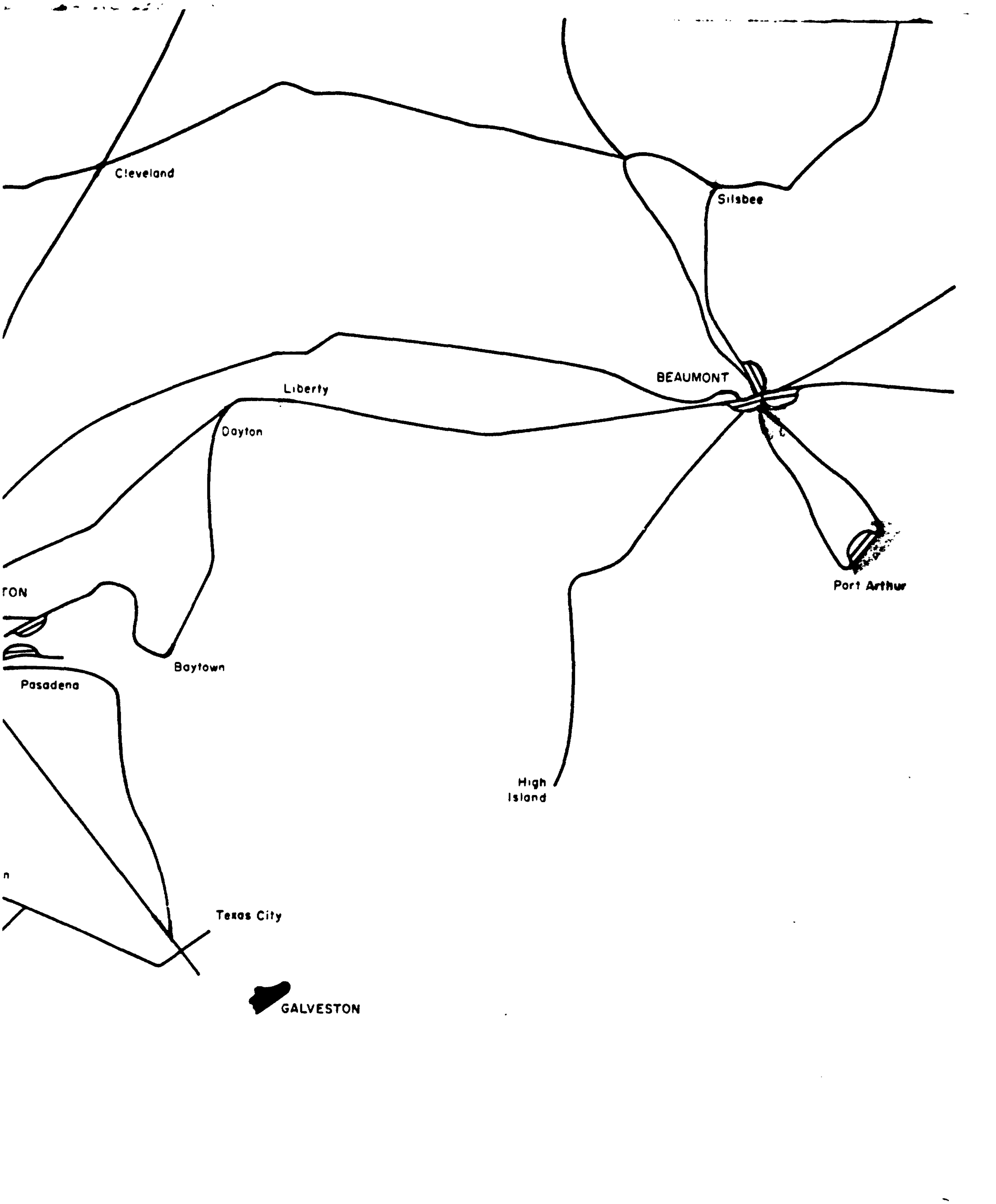
Considering all surviving facilities, the distribution of survival food represents 15 percent of the capability of the available yards in the two classification centers and 67 percent of the capability of the heavily used Beaumont-Somerville rail line. Surviving yards, operating with an average holding time of 2 days, could classify 5,000 cars per day. This level of operation would be consistent with maximum utilization of available long-distance rail lines.



Somerville
Navasota
Conroe
Brenham
TEXAS
Eureka
HOUSTON
Pasader
Glidden
Eagle
Lake
Rosenberg
Alvin
Wharton
Angleton
Bay City
Freeport

A


Navasota
TEXAS
Conroe
Cleveland
Libe
Dayton
Eureka
HOUSTON
Baytown
Pasadena
Rosenberg
Alvin
Wharton
Texas City
GALV
Angleton
Bay City
Freeport



C HOUSTON

CITIES LOST
REMAINING

Los Angeles Rail Activity Center

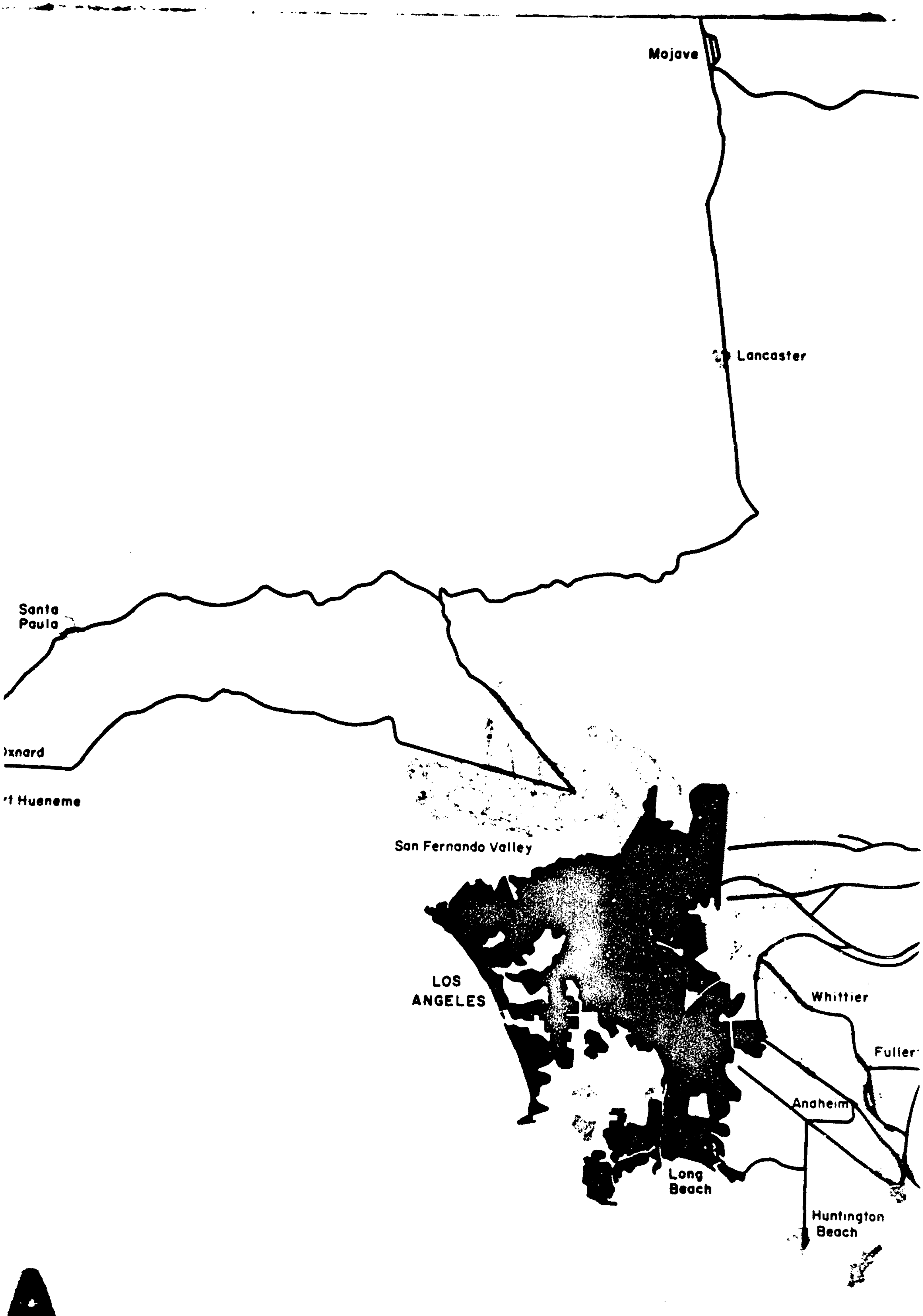
Nuclear weapons directed against Los Angeles, San Bernardino, and San Diego could isolate almost 2 million survivors in the coastal area between Los Angeles and San Diego and in the valley between Los Angeles and San Bernardino. Rail delivery of food to these people would depend on the survival of the Colton line, south of San Bernardino. The track itself has a 66 percent probability of avoiding destruction, but the possibility of surviving damage or blocking occasioned by flying debris is only 33 percent. Radioactive fallout in this area would be approximately 3,000 r/hr with the possibility of a higher level due to the downwind pattern. This level could delay re-entry for at least one month, during which time the food supply might become critical. This problem appears serious enough to warrant unusual measures for clearing and repair. Crews might travel in shielded cars, working in exposed areas for only one or two hours. Much of the work might be performed with special mechanical equipment which would properly shield the operator.

In the absence of this critical rail line, more than 5,000 tons of food per day would have to be transported over the San Jacinto Mountains by truck or down the coast from Ventura by water. The terminal problems associated with the daily transfer of food from 149 freight cars to trucks or barges would be enormous.

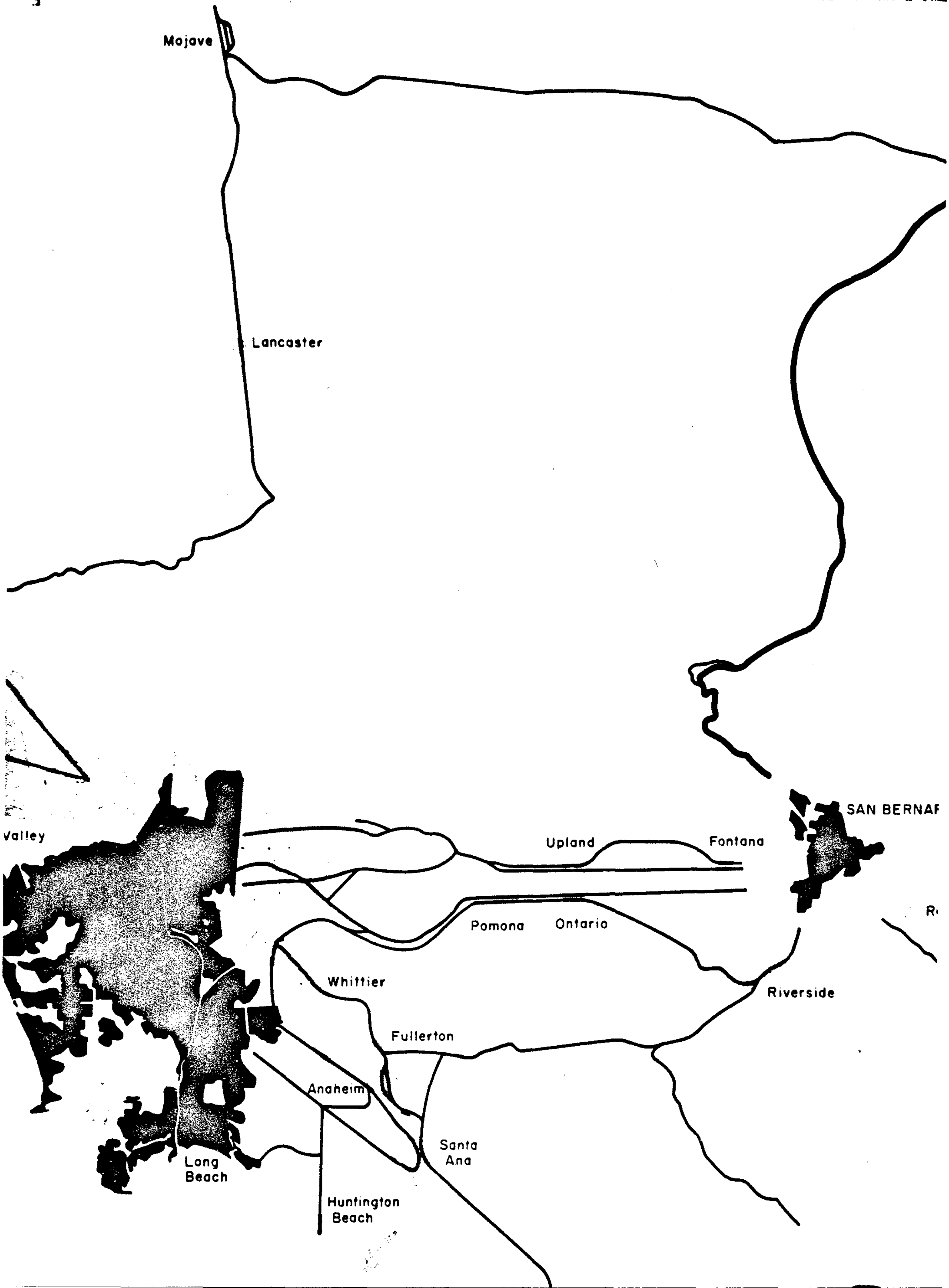
The logistic problem would be intensified by the destruction of all nearby yards. The classification load would have to be shared among yards at Barstow, Mojave, and Yuma, Arizona. The destruction of principal industrial areas could well leave sidings as well as support yards in short supply, complicating the delivery problem and requiring careful classifications at these remote yards.

The 690-mile belt line around Los Angeles, if it could be called such, would connect the outskirts of San Diego to Yuma, Phoenix, Barsow, Mojave, and Oxnard. Connections with other rail activity centers would be available through the double track east of Barstow and the single track from Barstow to Salt Lake City. Rail lines to San Francisco through the central valley or along the coast would be cut. Because of common supply lines, the needs of San Diego, Imperial, Ventura, Santa Barbara, and Kern counties must be considered in the analysis of the Los Angeles rail activity center. Rail deliveries of 30 cars per day could be made from Yuma to survivors near San Diego. An additional 81 cars per day could move from Barstow or Mojave to Oxnard and Santa Barbara to serve the 1 million survivors in the north coastal area and San Fernando Valley. The 400,000 survivors in Kern, San Bernardino, and Riverside counties could be served directly from Barstow.

Until the Colton line became available, the balance of the food would have to be transferred to highway or water carriers. Because of the large volume and long distances involved, the supply of food for survival would require 38 locomotive units and perhaps as many as 1,000 trucks carrying average loads of 10 tons. Food supply would utilize 17 percent of the capability of the surviving yards and tax the rail line from Mojave through Lancaster to 80 percent of its capability. Clearly, the recovery of the Los Angeles area would be impeded by transport difficulties.



Mojave
Lancaster
Santa Paula
Oxnard
San Fernando Valley
LOS ANGELES
Whittier
Anaheim
Long Beach
Huntington Beach


Mojave
Lancaster
Valley
Upland
Fontana
SAN BERNAF
Pomona
Ontario
Whittier
Riverside
Fullerton
Anaheim
Santa Ana
Long Beach
Huntington Beach


LOS ANGELES
CITIES
LOST
REMAINING
RAILROADS
SINGLE TRACK
MULTI-TRACK
YARD
Barstow
CALIFORNIA
SAN BERNARDINO
Fontana
Redlands
Riverside
Banning
Indio

San Francisco Rail Activity Center

Rail transportation to more than 2 million survivors in northern California would depend on the survival of the rail lines between Davis and Fairfield which lie very close to assigned aiming points. The track has been inspected to determine the topography in the critical area. There appears to be no reason to increase the lethal radius of the track beyond 3,000 yards. Accordingly, it is 78 percent probable that this track would survive the direct blast effects and the secondary effects of the blast wave on rolling stock. A normal diesel locomotive would provide sufficient shielding from the estimated H + 1 fallout level of 1,800 r/hr to permit operation of trains over this line the day after the attack. For the first two weeks, it would be unwise for the train crew to occupy the caboose.

Rail transportation around the San Francisco Bay area would be severly handicapped by weapons directed at Sacramento, Stockton, and San Jose. The classification center for this area would have to be the Roseville yard--the only substantial yard which would survive. Roseville has good rail connections to the east and north. Some traffic from the north might be classified at Gerber to avoid the 114-mile detour from Sacramento through Marysville to Davis.

The small yard at Davis, the nearest classification point to the San Francisco Bay area, could do little more than break up preblocked trains for delivery to survivor areas. The existence of only a single track around the Marysville-Davis detour would dictate that freight on this line be handled in long trains. Efficient use of the Davis yard would require careful scheduling since only a small amount of overflow could be handled at Fairfield.

Traffic for the San Joaquin Valley could be moved in large blocks from Davis to Tracy for further classification and distribution as far south as Fresno. The coastal counties south of San Francisco would have to be served by highway or water because of damage inflicted on rail lines at San Jose. This traffic--640 tons per day--could be transferred to trucks at the extensive industrial sidings south of Hayward or to barges at Sausalito or Redwood City. It is likely that a fleet of 50 trucks, or their equivalent in barges, could provide delivery to Santa Cruz and Monterey counties.

The post-attack transportation of food around the San Francisco Bay area would place the greatest burden on the Davis yard. Freight car handling efficiency at this point would enhance the recovery of the entire area. The survival food load would represent 6 percent of the post-attack capability of the Roseville yard, and 27 percent of the capability of the Roseville-Davis detour.

N FRANCISCO
CITIES
LOST
REMAINING
RAILROADS
SINGLE TRACK
MULTI-TRACK
YARD
CALIFORNIA
Colusa
Marysville
Yuba City
Roseville
Woodland
Davis
SACRAMENTO
Santa Rosa
Sonoma
Napa
Petaluma
Fairfield
Vallejo
Lodi
Antioch
Concord
Pittsburg
Stockton
San Rafael
Richmond
Walnut Creek
Mill Valley
Berkeley
Sausalito
OAKLAND
SAN FRANCISCO
San Leandro
Tracy
Hayward
Livermore
So. San Francisco
San Bruno
San Mateo
Belmont
Redwood City
Palo Alto
Los Altos
SAN JOSE

VI FINDINGS

The variety of problems which confront the different rail activity centers do not lend themselves to statistical analysis nor do they fit into a framework of general conclusions. In the aggregate, these problems do, however, point to areas of expected difficulty where thoughtful preplanning can contribute to the effectiveness of the post-attack solution. In some areas, investment in equipment and facilities prior to an attack could materially improve post-attack capability. The findings presented here are not at variance with those reached after the initial study. In some cases the emphasis has changed. In all cases, findings result from a more detailed knowledge of the post-attack problems which might confront specific areas.

Management

Good management is essential to successful operation of the railroad system following a massive nuclear attack. This is not a new thought. It has been demonstrated in the past by the monumental confusion during World War I caused by the shipment to the East Coast of large quantities of freight which exceeded the load-handling ability of existing terminals. That the solution to this problem lay in effective management was demonstrated by the rigid freight car handling controls enforced during World War II. The rail system was undamaged in both of these situations. The concept of a rail system with main lines substantially intact, but with home offices 90 percent destroyed, and with many key support facilities unavailable is not pleasant. The resultant problems, while not insoluble, do involve serious, careful, and detailed preplanning.

In past emergencies, the railroads have responded quickly and vigorously. Management and operating personnel have a sound knowledge of detours available in the case of derailment or flood or other natural disaster. These problems are, however, localized and do not assure the ability to cope with extensive concurrent damage to the rail network in all parts of the country.

Lack of knowledge of the size and location of alternative yard facilities appears to be a particular shortcoming. In the experience of the railroads, yard losses have been restricted to those very few occasions resulting from floods and, in such cases, yard problems have always been subordinated to rail line problems. Operating personnel are not generally informed on location of emergency facilities, particularly those which are owned by other railroads or which lie outside major terminals and would, therefore, be of primary importance in post-nuclear-attack operations.

Yards

In Philadelphia, Chicago, Minneapolis, St. Louis, and Houston, successful freight handling following the attack used in this study would require coordinated operation of several small yards to provide a service now available from any one of several large yards. These small yards are not designed or adapted for such post-attack operation. In some cases, sorting functions would have to be split for series or parallel combinations of multiple yards. Only in rare instances would it be possible to isolate the functions of receiving, classifying, train make-up, and dispatching in different yards. Communication among these yards--now operated by different railroads--would be vital. Where the yards are physically separated by long distances, as in Minneapolis, transfer trains would have to be carefully planned to conserve time, motive power, and the limited capability of connecting rail lines.

Rail Lines

An equally important post-attack problem involves balancing traffic on the available rail lines. The principal rail lines together with their necessary detours must first be defined. Critical points, such as the Mississippi River bridge at Alton, Illinois, must be located and steps taken to assure that they can be effectively utilized. As radioactive fallout decays, the necessary clearing to open up new lines must be initiated. These activities require close coordination among all surviving segments of railroad management.

Train Dispatching

The capability of surviving rail lines depends to a large degree on the adequacy of communications and the effectiveness of train dispatching.

Without effective dispatching, trains would move under a permissive block signal. Speeds would be low, accidents would be more likely to occur, and congestion might completely block important lines.

Dispatchers would be handicapped for they would be utilizing unfamiliar lines, relying on faulty communications, and dealing with unfamiliar or inexperienced train crews. Furthermore, it is unlikely that the pattern of post-attack rail traffic would stabilize for some time. All of these factors contribute to the need for well-established operating procedures and extensive pre-attack planning for post-attack eventualities.

Rolling Stock

One important function of home office management today is the long-distance, long-term dispatching of rolling stock.

Freight patterns vary by day, week, month, and season. Long before the grain harvest in the Midwest, empty cars are directed to preplanned sidings to be available for this traffic. Similarly, ore cars are prepared for the opening of the Great Lakes in the spring.

The combination of the loss of experienced home office personnel, the irregularity of freight movement, and inability to anticipate requirements in advance could lead to rapid and serious disparity in inventories of empty freight cars.

This deficiency could best be met by emphasizing operating procedures which would be effective in the post-attack period and attempting to instruct key personnel in all divisions and regions in these procedures and the problems which would have to be overcome.

Personnel

Post-attack management must recruit a labor force to man trains, yards, maintenance equipment, and signaling and communication equipment. With the unknown hazard of radioactive fallout, many employees may be reluctant to leave their shelters to face a hazard which is unseen and unsensed. Assignment of crews to clear vital rail lines and yards of debris would likely be a particular problem.

Pre-attack planning could contribute a great deal to this problem. Personnel could be trained to deal with nuclear fallout hazards. Personnel assignments, tasks, and control techniques could be established and publicized among all management levels.

Communications and Signaling

In this analysis, post-attack rail line capabilities have been adjusted to reflect anticipated communication and signaling difficulties.

Both services depend to a great extent on the availability of electric power. Battery-operated signals still need recharging from a low voltage line in order to function over an extended period of time. Although it is difficult to imagine that the extensive electric power grid system in the United States would be destroyed by even a massive nuclear attack, the destruction of large steam plants in metropolitan localities might result in the loss of power over large areas. Certainly, availability of this energy source is sufficiently important to warrant further study. The railroad industry could materially enhance its post-attack operation by installing stand-by generating units at key yards and control points which lie outside population and industrial centers.

In the initial study, it was learned that short-range post-attack communications probably could be established using surviving facilities. A cursory analysis, however, indicates that it may be difficult to establish long-range communications. It is important that serious attention be given to means of emergency long-range communications, for without such a system, long-distance and long-term car dispatching cannot be accomplished, nor can long-distance rail lines be effectively controlled.

Freight Transfer Devices

As a result of the contemplated attack, New York City, San Francisco, and possibly Los Angeles would face the problem of transferring large quantities of freight from rail carriers to other conveyances in order to reach survivors not accessible by rail. In other areas, freight cars would have to unload at makeshift terminals, possibly while under the threat of radioactive hazards. In view of anticipated shortages of yard and siding facilities near large cities, it would be desirable for the transfer or unloading to be accomplished as quickly as possible. Fast turnaround would also permit high utilization of the surviving rolling stock.

Innovations recently introduced by the rail industry offer possible solutions. Piggyback trains of 40 or 50 cars are commonly loaded and unloaded in 3 to 4 hours. Railroads and their subsidiaries now own over 13,000 piggyback flatcars and can be expected to continue buying them in large numbers. Nevertheless, this service is unlikely to comprise more than a small fraction of all freight movement, and thus piggyback shipments would have to be handled as a special class.

The next step in freight unitization beyond piggyback is containerization. This concept involves systems of reusable containers designed on a module to permit small units to fit into large units. The maximum size is comparable with the size of a highway van. If containerization were sufficiently widespread it could offer excellent solutions to both freight transfer and freight unloading. Containers also are more economical than trailers in the use of space aboard marine carriers. These units could be handled on chassis or casters or by fork lift truck, straddle carrier, or overhead crane. Their principal disadvantages are difficult inventory control, return of empties, and efficient utilization of shipping space and weight.

Large piggyback and container terminals, expensive in terms of both land and capital, now tend to be established near large cities where traffic levels are high. Their location at remote sites would be strictly a defense expedient. Nonetheless, some means of fast freight handling for both transfer and unloading would substantially improve post-attack rail operations.

Significance of Surviving Facilities

In the initial study, an effort was made to present post-attack facility capabilities in a statistical framework. It was recognized at that time that such a presentation might mask individual differences; however, the limitations of that effort did not permit a more exhaustive inquiry. It is intended that the results presented here for the 12 rail activity centers studied supersede those published in the earlier report.

Rail Lines

It is highly unlikely that the surviving rail lines, either interstate or local, could be uniformly loaded in response to a transportation demand such that each would carry traffic in proportion to its capability. Each traffic pattern would concentrate the load on one or more lines. There would probably be an optimum pattern which would permit the level of traffic to be maximized. The traffic patterns presented in Section V are neither the only possibilities nor are they likely the optimum patterns. They do, however, represent a considered solution which might be better than that reached on the basis of imperfect post-attack information.

Table II identifies the rail line in each activity center whose capability would be most nearly reached by the proposed traffic pattern. It is of interest to note that this critical line is in no case a principal line of the rail transportation model, but rather a limitation of the individual rail activity center. This observation would lead to the generalization that as far as rail lines are concerned post-attack rail

Table II

CRITICAL POST-ATTACK RAIL LINES--CAPABILITY
COMPARED WITH FOOD TRANSPORTATION REQUIREMENTS

Rail Activity Center	Critical Rail Line	Service	Capability (trains/day)	Food Traffic As a Percent of Capability
New York City	Poughkeepsie–Towners	BL 1/	45	31%
Philadelphia	Coatsville–Norristown	BL	45	18
Baltimore	Hagerstown–Frederick	S 2/	15	13
Pittsburgh	Aliquippa–Dickerson	BL	15	40
Toledo	Several	S	15	13
Chicago	Joliet–Gary	BL	120	26
Minneapolis	Glenwood–Altocna	BL	15	40
St. Louis	Bridge at Alton	B 3/	15	66
Kansas City	Leavenworth–Bonner Springs	S	15	33
Houston	Beaumont–Somerville	BL	15	67
Los Angeles	Mojave–Lancaster	BL	15	80
San Francisco	Roseville–Davis	BL	15	27

1/ Belt line.
2/ Supply line connecting survivor area to belt line.
3/ Bridge.

transportation would be limited by the capability of the rail activity centers. While conclusive evidence is not available, this is probably a safe statement.

Yards

The logistic analysis of 12 rail activity centers clearly pointed out that the classification capability of the center is not the sum of the capabilities of all surviving yards.

Railroad switching operations in the post-attack period would have to resemble present operations. In each activity center, a classification center would have to be designated where long-haul traffic would be classified. Cars designated for local delivery would then be rehandled at support yards where delivery trains would be made up. These support yards might be part of the classification center or some distance away. It becomes evident when considering the problems of communication and transport between the main activity center and an outlying point that support yards could not supplement or replace yards in the classification center if physically removed from them. Finally, some switching tracks would be needed at each destination. These would likely vary from converted passing sidings to rather large yards whose value would be reduced by their positions on dead-end tracks.

The tabulation of post-attack capability differs somewhat from that presented in the initial study. In the earlier work, post-attack yard capability was determined from a statistical tabulation of the capabilities of all surviving yards in the Resource Compendium. The revised figures in Table III include the additional classification of food carrying cars not directly derived from the rail transportation model. The yard capacities are those of the classification center alone, although some of the yards in this center may have come from one of the following sources:

1. Yards in the Resource Compendium but outside the physical limits of the rail activity center.

2. Changes since 1955 to yards which were included in the Resource Compendium.

3. Yards added as a result of this research.[1/]

1/ See Appendix A for a discussion of sources of data.

Table III

POST-ATTACK CLASSIFICATION YARDS—
CAPABILITY COMPARED WITH FOOD TRANSPORTATION REQUIREMENTS

Rail Activity Center	Classification Load 1/ (cars/day)		Switching Center Capacity (cars)	Total Load 2/ As a Percent of Capability
	Interstate 3/	Local 4/		
New York City	860	306	7,600	31%
Philadelphia	540	178	15,000	10
Baltimore	350	36	10,000	8
Pittsburgh	1,180	32	13,000	19
Toledo	880	16	20,000	9
Chicago	4,710	72	57,000	17
Minneapolis	1,290	49	5,000	54
St. Louis	1,280	78	12,400	22
Kansas City	2,390	46	6,400	76
Houston	680	60	10,000	15
Los Angeles	370	293	8,000	17
San Francisco	60	169	8,000	6

1/ Loaded and empty.
2/ Based on average yard holding time of two days per car.
3/ Interstate classification load equals the product of the classification factor and the sum of loaded and empty cars per day moving on each model link meeting at the rail activity center.
4/ The classification load imposed by local traffic in addition to interstate classification which would release cars for local delivery.

Post-attack yard information given in Table III is intended to supersede that given in Table 33, page 154 of the initial report. It is interesting to note that only in the case of Minneapolis and Kansas City are the figures of Table III appreciably less favorable than those of the earlier report. Nonetheless, the figures given in Table 33 for rail activity centers not analyzed in this report should be used cautiously.

Rolling Stock

In addition to interstate shipments as developed in the initial study, food distribution is envisioned in this report to include the transportation of food stocks available within the state to needy survivors in the rail activity centers. The magnitude of both movements is indicated in Table III. The accomplishment of this local transportation would require the services of additional locomotives and freight cars.

In the earlier study it was found that the percentage of loss of switching locomotives would be higher than that of line-haul locomotives. This is attributable to the location of switching locomotives in large yards in cities and on industrial sidings in areas of heaviest damage. The effect of the high percentage of loss of switching locomotives would be made more critical by the post-attack requirement placed on these locomotives to transfer incoming freight cars among surviving yards and to points of distribution which would serve the surviving population. The 12 rail activity centers studied would require a total of 274 locomotive units in addition to those available in the surviving yards. Some would be needed in small support yards which do not now have switching locomotives assigned. Most of them would be used in the transfer and distribution activity. These additional units would have to come from the inventory of line-haul locomotives.

An evaluation of all motive power requirements for moving survival food would depend on the number of switching, transfer, and distribution locomotives needed by the 25 rail activity centers not studied. It seems reasonable that 330 units might be required for this service, or a total of about 600 for all 37 rail activity centers. When these 600 are added to the 1,550 engaged in interstate food movement, the total represents 14 percent of all locomotive units surviving in the United States. It is to be noted that this total does not include units assigned to the classification centers which could presumably handle freight other than food.

Using the rolling stock equations developed in the initial study, it is possible to estimate the additional burden which local food distribution would place on the surviving freight cars. With a knowledge of the distribution pattern for each rail activity center, the number of switching movements and the number of car-miles generated each day can be estimated. When this knowledge is combined with the elapsed time per switching movement of 2 days and an appropriate delay for unloading, it can be demonstrated that 43,700 additional cars would be needed to support local distribution for the 12 rail activity centers studied. This requirement would not be meaningful when compared to interstate requirements unless the needs of all of the rail activity centers were included. Accurate determinations of these needs cannot be made without detailed analyses of each rail activity center; however, projections can be made on the basis of the 12 centers studied. From these projections it is estimated that local food distribution to all 37 rail activity centers would require the commitment of 96,000 additional cars, or a total of 192,000 freight cars. This total number represents 16.5 percent of the surviving freight cars.

Radioactive Fallout[1/]

It has already been pointed out that the effective shielding afforded by a locomotive would permit trains to travel through fields of relatively heavy fallout soon after an attack. The more detailed analyses of rail activity centers now indicate that the most important rail facilities would be those on or near the belt line, some distance from the area of heavy damage and intense fallout. The majority of the facilities near the belt line would be subjected to only moderate fallout and hence could be placed in operation shortly after the attack.

Many damaged yards would be subjected to fallout levels less than 800 r/hr. Repair forces could enter these yards one to two weeks after the attack and continue to work in the open, provided good shelter would be available for nonworking hours. Yards destroyed by the blast effects would commonly be denied for a much longer time, often a matter of months.

In Los Angeles, San Francisco, and St. Louis, there would likely be tracks which would have to be cleared in spite of high radioactive fallout. Mechanical equipment, which can be adequately shielded and operated without the assistance of men on the ground, offers the best means for

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1/ A comprehensive presentation of radioactive fallout in terms of rail facilities is given in Section V of the initial study.

accomplishing this clearing. Pre-attack investigations of clearing techniques could prove invaluable in those areas where post-attack clearing would be important.

Appendix A

SOURCES OF DATA

An analysis of specific rail activity centers requires data concerning the post-attack distribution of population, rail lines, and yards. Population distribution is available by county from the damage assessments which determine casualties, both blast and radiation, for the attack used in this analysis. The damage assessment work was performed by SRI under contract to OCDM.[1/] The data available on rail lines and yards require further explanation.

Rail Lines

The rail network analyses were based on information available from the following series of maps.

1. Army Map Service, Map No. 8204, Edition 5-AMS, Scale 1:2,500,000, Washington, D.C., 1957.

2. Army Map Service, Series V 402, Edition 1-AMS, Scale 1:500,000, Washington, D.C., 1956.

3. Rand McNally Handy Railroad Atlas of the United States, Rand McNally and Co., New York: 1958.

4. U.S. Geological Survey, Transportation Maps, Scale 1:250,000, U.S. Coast and Geodetic Survey, Washington, D.C., various dates.

These were supplemented in a number of cases by system maps of individual railroads and city and county maps. Where inconsistency was observed, railroad system maps were considered to be the most authoritative source. In several instances where track configuration was important and maps indistinct, personal inspections were made.

1/ Stanford Research Institute, Attack Damage Digest, SECRET, Restricted Data.

Yards

The Resource Compendium prepared by SRI for OCDM was the point of departure for the analysis of railroad yards. The yard information in this compendium identified by size, location, and other facilities some 595 classification yards that the operating railroads considered to be of major importance. The identification information was subsequently coded and a damage assessment made by computer. The results of this work formed the basis for the conclusions concerning yards given in the earlier report. It is important to note that only 131 of the assigned locations can be considered exact. Other assigned locations correspond to standard census points within a city or county. In the more detailed work reported here, all of the yards located in the 12 rail activity centers were carefully plotted on large-scale maps. As a result, a number of location corrections have been made to the Resource Compendium data. Some of these changes are significant. In Toledo, for example, the change in location of two very large yards from a standard county census point location to their actual geographical position resulted in a significant improvement in the post-attack posture of the entire rail activity center.

Classification yards deal in units of freight trains, receiving and sorting freight cars, remaking and dispatching trains. These activities are distinct from those of a freight terminal or support yard which is concerned with the movement of individual cars--setting out, breaking up, and consolidating. Although their physical configuration is different, there is no reason why, in an emergency, the functions of these installations could not be interchangeable.

In reporting classification yards, some railroads omitted adjacent terminal facilities. Yard data in the Resource Compendium have been revised to include these facilities where possible. Other changes have been made to reflect enlargements or abandonments since 1955. These changes together with the location changes are tabulated in classified Appendix D.

Since a large portion of the major classification yards in a number of rail activity centers would be destroyed, it is desirable to know what terminals and support yards might be available as replacements. Unfortunately, the size and location of all of these yards cannot be determined exactly without an exhaustive survey of individual railroads. The railroads do, however, report miles of yard track to the Interstate Commerce Commission (ICC) as follows:

Type of Road	Miles of Yard Track
Class I Railroads[1/]	59,660
Class II Railroads[2/]	1,230
Switching and Terminal Companies	7,640
Total	68,530

Of this total, the major classification yards in the Resource Compendium account for 23,500 miles or 34 percent. The balance of the yard track must lie in the large number of terminals and support yards, some of which are very small. Although these yards may be of little importance for classification in present-day rail activities, they might very well be vital to a highly disrupted rail activity center.

In the absence of published data giving size and location of terminal and support yards, a number of techniques were used to obtain this information where it was vital to the post-attack functioning of a rail activity center. Some yards were identified from city, county, and large scale (1:25,000) area maps. Other locations were obtained through interviews with railroad personnel. When none of these sources yielded satisfactory results, selected railroads were requested to supply the desired information. A personal inspection was warranted for four rail activity centers where the yard situation was especially critical (Philadelphia, St. Louis, Kansas City, and Houston). These techniques developed size and location information for 455 yards with an estimated 10,000 miles of track. These data are not intended to be added to the Resource Compendium as they are obviously biased toward the rail activity centers studied; however, because of their importance to the conclusions reached in this work, they are tabulated in classified Appendix D.

In addition to terminal and support yards, the railroads have 27,600 miles of way-switching track plus a great many industrial sidings which could be used in an emergency. Because of the small size and enormous number of these switching tracks, none have been individually identified.

1/ Line-haul railroads having annual operating revenues of $3,000,000, or more.

2/ Line-haul railroads smaller than Class I.

Appendix B

RAIL TRANSPORTATION MODEL NODES AND LINKS

The rail transportation model was carefully developed and presented in the initial study. The exact composition is presented again, as Tables B-I and B-II, in order that the reader might easily be able to identify the boundaries of each rail activity center and the principal rail lines which connect it to the balance of the rail network. The numbers in parentheses are designations established by the U.S. Census Bureau for identification of standard metropolitan areas and counties.

Table B-I

COMPOSITION OF RAIL TRANSPORTATION MODEL NODES

Node	State	Composition	
		Census Metropolitan Areas	Plus Additional Counties
Atlanta	Ga.	Atlanta (008)	
Baltimore	Md.	Baltimore (012)	
Birmingham	Ala.	Birmingham (017), Gadsden (052)	Calhoun (008), St. Clair (058), Shelby (059), Tuscaloosa (063)
Boston	Mass.	Boston-Lowell-Lawrence (018), Brockton (020), Fall River-New Bedford (047)	
Buffalo	N.Y.	Buffalo (021), Rochester (120)	Genessee (019)
Charleston	W. Va.	Charleston (025), Huntington-Ashland (062)	Boone (003), Lincoln (022), Logan (023), McDowell (024), Raleigh (041), Wyoming (055)
	Ky.	Huntington-Ashland (062)	
Chicago	Ill.	Chicago (028)	
	Ind.	Chicago (028)	
	Wisc.	Kenosha (070), Milwaukee (090), Racine (115)	
Cincinnati	Ohio	Cincinnati (029), Dayton (037), Hamilton-Middletown (058)	Brown (008), Clermont (013)
	Ky.	Cincinnati (029)	
Cleveland	Ohio	Akron (001), Canton (022), Cleveland (030), Loraine-Elyria (080)	Geauga (028), Medina (052)
Dallas	Tex.	Dallas (035), Ft. Worth (050)	
Denver	Colo.	Denver (039), Pueblo (114)	Douglas (018), El Paso (021)
Detroit	Mich.	Bay City (014), Detroit (041), Flint (048), Saginaw (123)	
Duluth	Minn.	Duluth-Superior (042)	Carlton (009), Itasca (031), Lake (038)
	Wisc.	Duluth-Superior (042)	Ashland (002), Bayfield (004)
Houston	Tex.	Beaumont-Port Arthur (015), Galveston (053), Houston (061)	Brazoria (020), Chambers (036), Fort Bend (079), Liberty (146), Orange (181)
Indianapolis	Ind.	Indianapolis (063)	
Kansas City	Mo.	Kansas City (069), St. Joseph (124)	Platte (083)
	Kans.	Kansas City (069)	Atchison (003), Douglas (023), Leavenworth (052)
Los Angeles	Calif.	Los Angeles (081), San Bernardino (129)	Riverside (033)
Louisville	Ky.	Louisville (082)	
	Ind.	Louisville (082)	
Marquette	Mich.		Delta (021), Dickinson (022), Iron (036), Marquette (052)

Table B-I (concluded)

Node	State	Composition	
		Census Metropolitan Areas	Plus Additional Counties
Memphis	Tenn.	Memphis (088)	
Minneapolis	Minn.	Minneapolis-St. Paul (091)	Goodhue (025), Washington (082)
New Orleans	La.	Baton Rouge (013), New Orleans (099)	Livingston (032), St. Charles (045), St. John the Baptist (048)
New York	N.Y.	New York-NE N.J. (100)	
	N.J.	New York-NE N.J. (100)	
Norfolk	Va.	Norfolk-Portsmouth (101), Hampton-Newport News-Warwick (170)	
Omaha	Nebr.	Lincoln (078), Omaha (104)	Cass (013), Dodge (027), Otoe (066)
	Iowa	Omaha (104)	
Peoria	Ill.	Decatur (038), Peoria (106), Springfield (141)	Logan (054), Mason (063)
Philadelphia	Pa.	Harrisburg (059), Lancaster (072), Philadelphia (107), Reading (117), York (167)	Lebanon (038)
	N.J.	Philadelphia (107), Wilmington (164)	
	Del.	Wilmington (164)	
Pittsburgh	Pa.	Altoona (005), Johnstown (067) Pittsburgh (109)	Blair (007), Cambria (011), Somerset (056)
	W. Va.	Wheeling-Steubenville (160)	
	Ohio	Wheeling-Steubenville (160)	
Portland	Ore.	Portland (112)	
	Wash.	Portland (112)	Cowlitz (008)
St. Louis	Mo.	St. Louis (125)	Jefferson (050)
	Ill.	St. Louis (125)	Monroe (067)
Salt Lake City	Utah	Ogden (102), Salt Lake City (126)	Morgan (015), Utah (125)
San Francisco	Calif.	Sacramento (122), San Francisco-Oakland (131), San Jose (132), Stockton (146)	Santa Cruz (044), Sonoma (049)
Scranton	Pa.	Allentown-Bethlehem-Easton (004), Scranton (134), Wilkes-Barre-Hazelton (163)	Carbon (013), Schuylkill (054)
	N.J.	Allentown-Bethlehem-Easton (004)	
Seattle	Wash.	Seattle (135), Tacoma (148)	Kitsap (018), Skagit (029), Snohomish (031), Thurston (034), Whatcom (037)
Tampa	Fla.	Tampa-St. Petersburg (149)	Manatee (041), Polk (053)
Toledo	Ohio	Toledo (151)	Erie (022), Ottawa (062), Sandusky (072), Wood (087)
Youngstown	Ohio	Youngstown (168)	Ashtabula (004)
	Pa.	Erie (045), Youngstown (168)	

Table B-II

RAIL TRANSPORTATION MODEL LINK DESCRIPTION

Link	Length (Miles)	Railroads Comprising	Road Characteristic: Double Track	Road Characteristic: Single CTC	Road Characteristic: Single Track	Link Capability (trains/day)
Atlanta-Baltimore	676	SAL, Southern	1		1	96
Atlanta-Birmingham	167	SAL, Southern			2	48
Atlanta-Cincinnati	489	L&N			1	24
Baltimore-Charleston	479	B&O			1	24
Baltimore-Philadelphia	95	B&O, PRR	2			144
Baltimore-Pittsburgh	321	B&O	1			72
Baltimore-Tampa	1,026	ACL		1		48
Birmingham-Louisville	425	L&N, Southern			2	48
Birmingham-Memphis	253	StLSF, Southern			2	48
Birmingham-New Orleans	384	L&N, Southern			2	48
Birmingham-Tampa	700	ACL, SAL			2	48
Boston-New York City	286	NYC	1			72
Buffalo-New York City	429	Erie, NYC	2			144
Buffalo-Youngstown	131	Erie, NYC, NYC&StL	2		1	168
Charleston-Cincinnati	204	B&O, C&O, N&W	1	1	1	144
Charleston-Norfolk	460	C&O, N&W	1	1		120
Charleston-Pittsburgh	282	B&O			1	24
Charleston-Toledo	339	C&O	1			72
Chicago-Cincinnati	283	C&O			1	24
Chicago-Cleveland	379	Erie	1			72
Chicago-Detroit	272	NYC, Wabash	1		1	96
Chicago-Duluth	468	C&NW			1	24
Chicago-Indianapolis	184	NYC, PRR			2	48
Chicago-Kansas City	451	AT&SF, CMStP&P, CRI&P	1	1	1	144
Chicago-Marquette	377	C&NW, CMStP&P			2	48
Chicago-Memphis	536	IC	1			72
Chicago-Minneapolis	402	CB&Q, C&NW, CMStP&P	2	1		192
Chicago-Omaha	495	CB&Q, C&NW, CMStP&P, CRI&P, IC	2	1	2	240
Chicago-Peoria	185	IC, Wabash			2	48
Chicago-Toledo	234	B&O, NYC, NYC&StL, PRR	3	1		264
Cincinnati-Cleveland	254	NYC	1			72
Cincinnati-Indianapolis	110	B&O, NYC, PRR	1		2	120
Cincinnati-Louisville	114	L&N, Southern			2	48
Cincinnati-Pittsburgh	307	B&O, PRR	1		1	96
Cincinnati-St. Louis	339	B&O			1	24
Cincinnati-Toledo	201	B&O, NYC		1	1	72
Cleveland-Toledo	107	B&O, NYC, NYC&StL, PRR	3	1		264
Cleveland-Youngstown	72	B&O, Erie, NYC, NYC&StL, PRR	1	1		336

Table B-II (concluded)

Link	Length (Miles)	Railroads Comprising	Road Characteristic: Double Track	Road Characteristic: Single CTC	Road Characteristic: Single Track	Link Capability (trains/day)
Dallas-Houston	281	AT&SF, CRI&P, T&NO			3	72
Dallas-Kansas City	568	AT&SF, CRI&P, StLSF			3	72
Dallas-St. Louis	688	StLSF			1	24
Denver-Kansas City	699	AT&SF, CRI&P, MP, UP			4	96
Denver-Omaha	558	CB&Q, UP	1	1		120
Denver-Salt Lake City	599	UP	1			72
Detroit-Peoria	413	Wabash		1		48
Detroit-Toledo	58	C&O, NYC, PRR	3			216
Duluth-Marquette	242	C&NW			1	24
Duluth-Minneapolis	150	C&NW, GN, NP			3	72
Houston-Los Angeles	1,635	AT&SF, SP-T&NO		5/6		40
Houston-New Orleans	356	MP, T&NO			2	48
Houston-St. Louis	798	MP			1	24
Indianapolis-St. Louis	241	NYC, PRR		1	1	72
Kansas City-Los Angeles	1,765	AT&SF, SP-CRI&P		1 1/3		64
Kansas City-Memphis	484	StLSF			1	24
Kansas City-Minneapolis	484	CRI&P			1	24
Kansas City-Omaha	199	CB&Q, MP, Wabash			3	72
Kansas City-Peoria	302	Wabash			1	24
Kansas City-St. Louis	283	CRI&P, MP			3	72
Los Angeles-Memphis	2,024	SP-CRI&P		1/3		16
Los Angeles-Salt Lake City	775	UP		1		48
Los Angeles-San Francisco	453	AT&SF, SP			3	72
Louisville-Memphis	380	IC, L&N			2	48
Louisville-St. Louis	280	L&N, Southern			2	48
Memphis-New Orleans	220	IC			1	24
Memphis-St. Louis	305	StLSF			1	24
Minneapolis-Omaha	367	C&NW			1	24
Minneapolis-Seattle	1,800	CMStP&P, GN, NP			3	72
New York City-Philadelphia	92	B&O, PRR	2[1]			288
New York City-Scranton	134	Erie			1	24
Peoria-St. Louis	167	IC, Wabash	1		1	96
Philadelphia-Pittsburgh	349	PRR	1[2]			144
Philadelphia-Scranton	154	PRR			2	48
Pittsburgh-Youngstown	80	B&O, PRR	2			144
Portland-Salt Lake City	896	UP			1	24
Portland-San Francisco	748	SP			1	24
Portland-Seattle	186	CMStP&P, GN, NP, UP	1			72
St. Louis-Toledo	447	NYC&StL			1	24
Salt Lake City-San Francisco	801	SP		1		48

1/ PRR maintains four track New York to Philadelphia.
2/ Triple track.

Appendix C

REVISED DAMAGE ASSESSMENT TABLES

When processing large amounts of data, it is difficult to appreciate the significance of individual items. If a portion of these data is later examined in depth, revisions and improvements almost necessarily follow. Such has been the case with the data concerning yards and rapair shops in the systems analysis of post-attack rail transportation in the United States.

In the text of this report, a number of instances have been pointed out in which yard coordinates have been changed from standard locations to actual locations. The sizes of some of the yards in the *Resource Compendium* have been changed to reflect the capacity of nearby support facilities, new construction, or abandonment. The damage assessment has been improved to reflect the probabilities that weapons will detonate at the points of aim. Finally, a great deal of new yard data has been introduced in order that the post-attack picture might be more complete.

During the course of this investigation it became apparent that improvements could be made to the computer program on which the earlier results were based. The program has been modified and revised damage assessment runs have been conducted for classification yards and for repair shops. Summaries of those runs are presented here.

Tables C-I, C-II, C-III, and C-IV supersede Tables D-1, D-2, D-3, and D-4, pages 202-209 of the earlier report. References to this basic information occur elsewhere in the first report but since the conclusions reached in that work need not be changed as a result of the new information, no effort has been made to modify other tables or the text to conform to the new data presented here. The reader should, however, exercise judgment in interpreting the older work, giving suitable emphasis to the data in this appendix and the balance of this report.

Table C-I

PRE-ATTACK AND POST-ATTACK INVENTORY OF
RAILROAD CLASSIFICATION YARDS AND REPAIR SHOPS
POST-1960 MILITARY ATTACK

	Pre-Attack Inventory	Damage Assessment				
		Destroyed	Damaged	Undamaged		
				>3,000 r/hr	300–2,999 r/hr	<299 r/hr
Classification Yards						
Region 1	67	2	0	0	1	64
Region 2	134	0	2	2	22	108
Region 3	54	2	2	1	2	47
Region 4	169	1	0	1	6	161
Region 5	56	5	8	0	1	42
Region 6	68	4	3	0	11	50
Region 7	23	1	1	1	0	20
Region 8	24	0	0	0	4	20
Total	595	15	16	5	47	512
Repair Shops						
Region 1	15	0	0	0	0	15
Region 2	57	0	1	1	10	45
Region 3	25	3	0	0	2	20
Region 4	56	0	0	1	2	53
Region 5	22	2	1	0	0	19
Region 6	39	2	3	0	6	28
Region 7	12	0	2	0	0	10
Region 8	20	0	0	0	3	17
Total	246	7	7	2	23	207

Table C-II

PRE-ATTACK AND POST-ATTACK INVENTORY OF
RAILROAD CLASSIFICATION YARDS AND REPAIR SHOPS
POST-1960 MILITARY AND POPULATION ATTACK

	Pre-Attack Inventory	Damage Assessment				
		Destroyed	Damaged	Undamaged		
				>3,000 r/hr	300–2,999 r/hr	<299 r/hr
Classification Yards						
Region 1	67	41	4	3	8	11
Region 2	134	77	9	5	21	22
Region 3	54	29	8	1	2	14
Region 4	169	114	4	0	16	35
Region 5	56	37	3	0	2	14
Region 6	68	29	4	9	4	22
Region 7	23	11	2	0	2	8
Region 8	24	11	1	0	3	9
Total	595	349	35	18	58	135
Repair Shops						
Region 1	15	8	0	0	2	5
Region 2	57	26	5	1	11	14
Region 3	25	14	1	0	2	8
Region 4	56	18	3	1	10	24
Region 5	22	11	1	0	0	10
Region 6	39	15	2	3	5	14
Region 7	12	7	2	0	1	2
Region 8	20	7	2	0	2	9
Total	246	106	16	5	33	86

Table C-III

PRE-ATTACK AND POST-ATTACK INVENTORY OF
RAILROAD CLASSIFICATION YARDS AND REPAIR SHOPS
POST-1965 MILITARY ATTACK

	Pre-Attack Inventory	Damage Assessment				
		Destroyed	Damaged	Undamaged		
				>3,000 r/hr	300-2,999 r/hr	<299 r/hr
Classification Yards						
Region 1	67	7	4	0	21	35
Region 2	134	14	2	1	62	55
Region 3	54	0	0	1	7	46
Region 4	169	1	4	48	116	0
Region 5	56	8	6	7	8	27
Region 6	68	8	11	28	19	2
Region 7	23	5	1	6	3	8
Region 8	24	1	4	2	3	14
Total	595	44	32	93	239	187
Repair Shops						
Region 1	15	0	1	0	5	9
Region 2	57	5	1	1	27	23
Region 3	25	0	0	0	4	21
Region 4	56	0	1	11	44	0
Region 5	22	3	0	6	7	6
Region 6	39	5	7	16	11	0
Region 7	12	1	2	5	2	2
Region 8	20	0	2	4	2	12
Total	246	14	14	43	102	73

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Table C-IV

PRE-ATTACK AND POST-ATTACK INVENTORY OF RAILROAD CLASSIFICATION YARDS AND REPAIR SHOPS POST-1965 MILITARY AND POPULATION ATTACK

	Pre-Attack Inventory	Damage Assessment				
		Destroyed	Damaged	Undamaged		
				>3,000 r/hr	300-2,999 r/hr	<299 r/hr
Classification Yards						
Region 1	67	47	1	6	10	3
Region 2	134	89	1	10	21	13
Region 3	54	36	1	2	6	9
Region 4	169	120	10	13	26	0
Region 5	56	45	0	6	4	1
Region 6	68	41	5	15	5	2
Region 7	23	15	1	1	2	4
Region 8	24	14	1	2	2	5
Total	595	407	20	55	76	37
Repair Shops						
Region 1	15	8	0	1	5	1
Region 2	57	34	0	4	14	5
Region 3	25	16	0	1	4	4
Region 4	56	25	3	10	18	0
Region 5	22	12	0	5	4	1
Region 6	39	18	3	13	5	0
Region 7	12	11	1	0	0	0
Region 8	20	9	1	5	3	2
Total	246	133	8	39	53	13