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TORNADO WIND DAMAGE TO BUILDINGS OBSERVED AFTER THE SARNIA TORNADO of May 21, 1953

by

J.D. McCrea

With a Supplement by D.C. Tibbetts

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PREFACE

One of the aims of the work of the Division of Building Research is the improvement in the design of buildings. The design of house construction in the past has been based largely on tradition and experience and it is usually impossible to state the degree of structural safety incorporated in existing house structures. In an effort to clarify this situation the Division is following two lines of approach. One is the execution of full-scale loading tests on houses; the other is the observation of performance of structures under actual conditions.

The probability of loads produced by high winds, and the proper choice of design velocities and of simplified design methods for wind action, are in themselves difficult problems. Tornadoes may produce exceptionally destructive wind velocities, but because of their rare occurrence and limited ground coverage, it is not generally considered necessary to design houses for these velocities. Thus, when a tornado strikes it may cause considerable damage and, as a giant full-scale loading test, provide an unusual opportunity to compare the performance of different types of buildings under high winds. It was for this reason that the Division decided to make an analysis of the damage to various types of constructions in the Sarnia area after the tornado of May 21, 1953.

Two assistant research officers of the Division Mr. J.D. McCrea of the Building Design Section and Mr. D.C. Tibbetts of the Building Practice Section, paid a visit to the Sarnia area shortly after the tornado. They received every possible assistance from those with whom they were in touch, with the result that they were able to compile a complete set of notes and a singularly extensive collection of photographs of all structural phases of the tornado damage. These notes and photographs are now on file with the Division.

So much interest has been expressed in this record that this summary report has been prepared and is now made available for those with special interests in this field. It is a summary only of the information obtained. The report includes a list of all the photographs now in the Division's files, but only a small selection of these are reproduced in the report. If any readers of this report wish to have further particulars or to examine any of the photographs listed, the Division will be glad indeed to try to arrange for this.

Ottawa,
February, 1957.

Robert F. Legget,
Director.

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TORNADO WIND DAMAGE TO BUILDINGS OBSERVED

AFTER THE SARNIA TORNADO

of May 21, 1953

by

J. D. McCrea

I Introduction

On May 21st, 1953 a tornado swept through Port Huron (Michigan), Sarnia, and London Township (Ontario). This tornado resulted in the loss of 7 lives, 2 in Michigan and 5 in Ontario, and in property losses amounting to $2,500,000 in Michigan, $4,000,000 in the city of Sarnia and $2,100,000 in rural Ontario. There have been only a few more destructive storms of this type on the North American continent during the period between 1900 and 1952. Many storms have resulted in higher casualty figures but this particular storm referred to as the "Sarnia Tornado", ranks with those causing the most extensive property damages.

The Division of Building Research of the National Research Council is naturally interested in and concerned with all aspects of wind action on structures. The damaged buildings in the path of this tornado were, therefore, investigated by two members of the staff of the Division and a number of features of interest to engineers concerned with wind load design problems were encountered in the analysis of these buildings. The meteorological aspects, an analysis of damage to various types of constructions, the maximum probable velocities, building regulations, fire aspects, and recommendations for tornado resistant construction are included in this report.

Attention is also drawn to a report "Observations on the Sarnia Tornado of May 21, 1953" by E. E. Massey of the Defence Research Board, dealing particularly with civil defence aspects of the storm (1).

II Meteorological Aspects

Tornadoes, (from the Latin tornare "to turn"), are probably the severest storms produced by nature. They are formed by the turbulent reaction that takes place when moist warm tropical air masses come in contact with cold polar air masses, which can lead to whirls of rapidly rotating air masses producing very high wind velocities. One authority on this type of storm describes the weather conditions preceding a tornado in the following words. "Several hours of abnormally warm humid and oppressive weather usually precede the formation of a tornado. The initial whirl at the cloud level may occur when the sky is entirely overcast or in cumulo-nimbus clouds that leave much of the horizon clear" (2).

Two physical forces that must be considered in building design result from this dynamic action. One is the extremely high velocity pressure due to the movement of the air in the circumference of the vortex or whirl; the other is the extreme negative pressure due to the centrifugal reaction of the circular air movements. The combination of these violent forces results in extensive damage, if not complete demolition, to all except the more substantially built constructions. The movement of the vortex through the sky has been described as being similar in appearance to the swinging motion of an elephant's trunk.

Records indicate that the forward speed of the vortex may vary from 0 m.p.h. to about 65 m.p.h. while the average, generally is about 45 m.p.h. The Sarnia storm had a forward speed of between 30 and 40 m.p.h.

Frequently the lower end of the vortex goes aloft during its travel and, therefore, the line of damage is sometimes discontinuous or sporadic. This was also true for the Sarnia tornado.

The width of the path may vary from as little as 100 feet to 2,000 feet. It was noted in the Sarnia storm that the forces involved were more intensive as the vortex narrowed in width. This was especially noticeable in the rural districts where the storm passed through groves of hardwood trees. In areas where the path was narrow, the trees were broken off 5 to 10 feet above the ground and the leaves were completely stripped from the branches, but in areas where the path widened, many leaves remained on the branches of the trees which were left intact, thus indicating the variation of the intensity of the storm.

The storm originated at Smiths Creek, Michigan, about 10 miles west-southwest of Port Huron and proceeded through Port Huron, Sarnia and London Township before going aloft northeast of Woodstock (Fig.1). It finally dissipated over Lake Ontario 40 miles due west of Watertown, New York. Actually according to reports from the damaged areas, there appeared to have been at least three separate parallel tracks or three separate tornadoes.

The weather earlier in the afternoon before the storm swept through the area, was described as hot and humid. The vortex was preceded by a severe hail storm. This hail storm was credited by many in Sarnia with clearing the streets of pedestrians, which explains the low number of casualties. The casualty rate was miraculously low considering that the destructive vortex of the storm passed diagonally through the centre of the main commercial district and the residential district of a city with a population of approximately 40,000. Ninety-seven commercial dwellings and 154 residences were damaged in varying degrees, from total destruction to minor structural damage, such as the collapse of parapet walls on commercial buildings, or the removal of clapboard siding from residential constructions. The casualty rate was as follows: deaths 0; hospital cases 15; hospital out-patients 33.

III Analysis of Damage

Since the storm traced its destructive path through commercial, residential, and agricultural districts, (Fig.2), there was ample opportunity to study its effects on the various types of constructions common to this area of the continent.

(a) Concrete Block Construction and Foundations

There were not many examples of concrete block construction in the commercial district of Sarnia, but, of the three examples reviewed, two one-storey structures were almost completely demolished. The third, a garage with a hotel occupancy on the second floor, appeared to have been damaged considerably by racking and some of the walls were out of line both laterally and vertically. Since this building had been in disrepair, however, and probably had been altered several times, it was impossible to determine whether the damage had been the result of forces of the tornado.

Upon examination of several structural failures in residential construction it was evident that concrete block foundation walls were inferior to monolithic concrete foundation walls because there were several concrete block foundation wall failures. The block walls either collapsed or were sheared off along the mortar lines. No example of monolithic concrete foundation failure was found. An example of concrete block failure is shown in Fig.3; (cf. also Figs. 7, and 16 to 23 in a report by the Canadian Defence Research Board (1)).

(b) Masonry Bearing Wall Construction

Another type of construction that received considerable damage was masonry bearing wall construction. This generally consisted of platform roof and floor construction keyed into the masonry bearing walls. Most of the buildings in this classification were the older buildings of the area and constituted a majority in the commercial district of Sarnia. Many had been successively weakened by the usual series of alterations that buildings in commercial districts undergo because of changes in use and occupancy. Examples in this group revealed considerable variation in damage. Examination showed that these differences were due to variations in exposure; differences in materials, workmanship, care in alterations; and number, placement and type of interior partitions.

The first buildings in Sarnia to experience the tremendous forces of the storm were of this type of construction along the river front on Front Street. Damage to these consisted of the removal of portions of the complete roof, or the collapse of the top-storey walls (Figs. 4, 5, 6). The Hotel Vendome received considerable damage to its third-and fourth-storey walls. Portions of these walls on the west side (facing the approaching storm) and the fourth-storey wall on the south side were blown out. The large, many-sided tower portion of the building received little damage, indicating the effectiveness of laterally supported or buttressed masonry walls.

One building that received extensive damage was the two-storey building on Christina Street occupied by a bank and furniture store. The entire roof was removed together with the second-storey wall. The furniture in the second floor show-room appeared to have been relatively undisturbed, and was entirely exposed to the elements after the storm had passed (Fig.7). Water damage to the first floor was due to the second floor sprinkler system which was broken in the storm.

The entire stage portion of the Imperial Theatre, consisting of a large expanse of laterally unsupported masonry bearing wall, was totally demolished (Fig.8) The remainder of the building, constructed of a steel and reinforced concrete frame, was damaged only in the bays adjacent to the stage portion of the building. The damaged portion of the building was on the lee side of the approaching storm and failure probably was due to the differential of pressure between the atmospheric pressure on the inside of the building and the low pressure of the core of the vortex on the outside.

Other buildings of this type received considerably less damage. In some instances, only the parapet walls and portions of the roof were damaged.

The buildings in this classification were largely responsible for the great quantities of rubble, sometimes more than 10 feet deep, that filled adjacent streets and blocked the thoroughfares for two or three days until the clean-up crews could clear them.

(c) Steel and Concrete Framed Buildings

The buildings in this category received no damage that could be classed as structural damage. Although there were only a few examples of this type of construction in Sarnia, it was evident, from the examination of those exposed to the forces of this storm, that they were capable of resisting these forces.

The telephone exchange building, a reinforced concrete structure, was, as far as could be determined, in the centre of the path of the storm. Two houses adjacent to it were completely demolished, and a car was hurled over the side wall and lawn against the side of the building. The subsequent investigation of this building and a review of reports of the damage by company officials, failed to show any strictly structural damage. A crack in the chimney wall was noted after the storm and a few of the coping stones were knocked from the building. The exterior wall, which was struck by the car, was damaged slightly. The majority of windows in the building were broken and the venetian blinds were sucked out. The door-closing devices on all doors that were equipped with them were damaged and had to be repaired, indicating that the doors had acted as pressure release valves. The breaking of the windows and opening of the doors presumably contributed to the avoidance of more extensive damage to this structure. Probably the most costly damage was the collapse of the suspended ceilings. Evidently these enclosed air spaces exerted a pressure sufficient to collapse these membranes outward as the low pressure core of the storm passed over the building.

(d) Residential Wood Frame Construction (urban and rural)

Damage to residential construction varied considerably. Some houses were entirely demolished (Fig.9); others had their roofs torn away (Fig.10); and some were moved off their foundations (Fig.11). These were the more severe results of the storm's passage. Less severe damage consisted of loss of portions of the roof or of roofing material, loss of siding, or damage from flying debris, such as parts of other buildings and falling trees.

The loss of roofs and movement off foundation indicated inadequate fastening details at these points. In many of these cases adjacent houses, apparently built by different contractors, did not receive similar damage (Fig. 10).

Most of the farm residences were of masonry veneer construction and generally suffered extensive damage, if not complete demolition (Fig. 12). The completeness of this damage probably was due to the fact that, in most cases, these buildings were completely exposed to the full effects of the storm.

(e) Farm Buildings (barns, sheds, silos)

The barns in this area were constructed of heavy timber frames fastened together with wooden dowels with a 1-inch (nominal) lumber siding. Many of these structures suffered complete demolition.

The only farm structures that withstood the effects of the storm were the circular-shaped concrete silos. In many instances, the silo was the only indication from a distance that there had been any farm buildings on a farm. The rest had been completely demolished (Fig. 13).

(f) Building Decorations, Signs, and Parapet Walls

Some of the downtown buildings had extensive and ornate decorations, such as cornices and figurines, attached to their exteriors over doorways and windows. Many of these decorations, some of which were iron castings, were blown off or loosened. Signs were damaged in nearly every case in the centre of the storm, either by the wind or wind-blown debris. These decorations were often responsible for damaging portions of the structural parts of the buildings.

Parapet walls were damaged extensively. It is reasonable to assume that the collapsing of these walls triggered chains of events that resulted in the demolition of the top portions of many buildings. The parapet walls normally failed at their weakest cross-section, usually at the roof line where the horizontal wall section is reduced in area to support the roof framing members. Once failure occurred at this point, probably when the leading portion of the circumference of the vortex passed the building, the roof framing members were exposed with nothing to restrain the lifting of the roof, when the low pressure centre of the storm followed. This left the cantilevered unsupported top-storey walls subjected to the velocity pressures of the trailing portion of the circumference of the vortex.

(g) Tree Damage and Sidewalk Damage

It was interesting to note the difference in the type of tree failures between the low, level country around Sarnia and the rolling countryside north and northwest of London. Portions of the roots of many trees in Sarnia were pulled out when the trees toppled over, while the trees in the London Township district, in many cases, were broken off 5 to 10 feet above the ground (Fig.13). This seemed to indicate that the main differences in tree damage were due to a variation in the average ground water table levels in the two areas. The water table level was closer to the ground surface in Sarnia and thus the root penetration was not as deep as in the London Township. Of the two types, the failure at the roots necessitated more clearing up after the storm because generally the trunk had to be sawed off at the base before any clean-up operation could be started. This type of failure also caused considerable damage by breaking portions of the street surfaces, curbs, and sidewalks. Tree debris in the London Township could be cleaned up merely by pushing it aside.

IV Probable Maximum Wind Velocities

The variation in the intensity and direction of the vortex winds made it difficult to find examples of structures suitable for analysing with any degree of accuracy in relation to the magnitude of the velocities of the winds. Two examples, however, were found which lend themselves to a velocity estimate; one, a reported freight car derailment in Michigan and; an electric substation structure that was noted during the investigation. The substation appeared to have experienced the full force of the tornado, on the outskirts of the residential district of Sarnia, as a house within 15 to 20 feet of it was totally demolished. These structures, or similar ones, have undergone destruction tests and from calculations, using accepted wind tunnel determined shape coefficients, it was determined that probably a maximum velocity of 170 m.p.h. would have caused this structure to fail.

It is reasonable to assume, therefore, that the velocity of the vortex winds did not exceed 170 m.p.h., plus 2 x 30 m.p.h. (the forward speed) or 230 m.p.h., the probable velocity of the eastern portion of the counter-clockwise whirl. The substation had been exposed to the western, less severe portion of the whirl. An open-framed structure of this type probably would not be appreciably affected by the suction forces of the core of the vortex. It is believed, therefore, that this example indicates that the velocities did not exceed this figure. The freight car derailment, according to some calculations, could have been caused by velocities of about 150 m.p.h.

These estimates are in reasonable agreement with those of maximum probable velocities made by James D. Marshall, Consulting Engineer, Kansas, and Captain George W. Reynolds, U.S.A.F. of St. Louis, Missouri (2). These two investigators concluded that wind speeds of 200 m.p.h. could have caused the damage resulting from the storms that they investigated. Some estimates have been made as high as 500 m.p.h., which would produce a velocity pressure of 830 lb. per sq. ft., whereas a 200 m.p.h. wind produces forces somewhat over 100 lb. per sq. ft., which is more in keeping with the probable margins of safety of structures that have withstood the forces of a tornado.

V Building Regulation Aspects

The forces of the storm uncovered many violations of good building regulations and good building practice. Examples of greatly overloaded floors were found, especially in the case of a remodeled house where the first floor was used as an automotive show-room and the floor immediately above as a stock room that included the storage of engine blocks. Another case of overloading was a series of 30 to 40 ft. long laterally unsupported steel beams carrying the bedroom section of a hotel immediately above a garage. These beams showed considerable evidence of lateral and vertical buckling. The mixed occupancy with the exposed unprotected steel supporting the hotel floor must be considered a serious condition.

This case, and the probability of many other similar violations, caused the relatively new building inspection department considerable concern. Here, it was existing construction that constituted the biggest problem, as new construction employed present day accepted building regulations.

This inspection showed that buildings designed and constructed in accordance with currently accepted building standards experienced much less damage than those not so constructed. This was especially true of steel and concrete framed buildings as compared to the older masonry bearing wall constructions.

In Robbins Fleming's classical work, Wind Stresses in Buildings, reference is made to some generalizations by F.E. Schmitt, editor of Engineering News Record, on the Florida hurricane of 1926, where wind velocities of 128 m.p.h. were registered. The best-built structures resisted the storm either completely or with minor damage. Good construction was not dependent upon specific materials. It was also observed that anchorages often failed, in the lifting, rolling over or bodily shifting of houses and garages. Hollow tile and concrete block walls failed extensively. Roofing materials made an unsatisfactory showing and many roofs were ripped away, either completely or in part. Windows were shattered everywhere; and window construction was reported to have been frequently the first damage. The same statement could be made for the Sarnia tornado.

In the periodical, Practical Builder August 1953, reference is made to the tornado of Worcester, Mass. June 9th, 1953. A frame house that had been built with about twice as many nails in the framing connections, stronger bracing, heavier lumber, anchor bolts, etc., withstood what were apparently the maximum forces of that tornado.

It appears, therefore, that by increasing the currently recommended fastening details for roofs, floors, and walls, especially in tornado-susceptible areas, the losses could be reduced considerably. It would also appear that steel and concrete framed buildings, built according to accepted building regulations, were strong enough to resist structural damage. More attention should be given parapet wall details. If details similar to those outlined in Anchorage for Factory Roofs, Principles and Design Data (3) were incorporated in building design, in areas where tornadoes are possible, it is likely that many masonry bearing wall constructions would withstand tornado forces as well as the steel and concrete framed buildings.

VI Fire Aspects

Staff members from the Ontario Fire Marshal's Office inspected the fire aspect of the disaster. See A Report to the Fire Marshal - re: The Investigation into Certain Fire Aspects of Tornado Damages - The City of Sarnia, Ontario May 25 - 30, 1953 . The following is an excerpt from this report.

"The fact that no fires resulted from this storm can only be considered as a very fortunate turn of events. Undoubtedly the terrific force of the wind and the torrential rains that followed the wind inhibited the ignition of fires, but the fact remains that with the great amount of damage to the electrical system and gas system it could have produced a state of extreme hazard. That it did not result in a disaster is merely due to good fortune on the part of the citizens, and the extreme rapidity and efficiency of the officials of both the Hydro and the Union Gas Company in taking steps to alleviate the condition."

VII Recommendations for Reducing Tornado Hazards

The term tornado-resistant construction is used in this report to refer to structural elements and their components that are able to withstand the forces involved in such a storm. It is not intended that this term apply to surface damage, which, although superficial in nature, is usually costly to repair. Some examples are window breakage; loss of lightweight roofing, siding, flashings; damage to contents by rain or broken sprinkler piping; and damage from mud and flying debris to exterior and interior surfaces and building contents. Practically speaking, it is impossible to prevent this type of damage.

After completion of this investigation it seemed apparent that the extensive economic losses resulting from tornadoes could be kept to a practical minimum if the following recommendations were incorporated in specifications for buildings erected in tornado-susceptible regions:

1) Design all structural framing elements to withstand a velocity pressure produced by at least a 90 m.p.h. wind. The inherent margin of safety of present day construction probably will allow structures to resist all but the most violent tornadoes. Use shape or form factors such as those recommended in the National Building Code 1953 Design General Requirements.

2) Tie walls, roofs, and floors of masonry bearing walls and wood frame construction together to withstand the design forces as calculated in accordance with the first recommendation. Typical details of economical connection are set forth on page 14 of the publication Anchorage for Factory Roofs (3).

3) Avoid large expanses of laterally unsupported building walls.

4) Avoid excessively high and poorly tied parapet walls. Reinforce parapet walls to withstand a lateral load of at least twice the design load recommendations mentioned in 1).

5) Avoid ornamentation that is "placed" or "hung" on the building.

Glass, as an automatic means of venting enclosed air spaces, should be used only when adequate protection is provided for the occupants of the area under consideration until more data are collected on this aspect of structural protection. There were remarkably few casualties from flying glass in the telephone exchange building, perhaps because there were few instances where the occupants were openly exposed to large expanses of glass. It could not be determined, therefore, whether this low casualty rate was due to the glass breaking outwards, or whether the occupants were protected adequately by the telephone switchboards, that stood between them and the windows. It is possible also that some casualties thought to be caused by flying glass were due to fragments from the collapsing suspended ceiling or vice versa. With the introduction of radar detecting devices, it may be possible, in the future, to give adequate warning to the occupants of such buildings so that refuge might be taken in the basement or in other adequate storm shelters.

VIII Conclusion

It appeared from this investigation that, essentially, tornado-resistant construction can be achieved economically, by applying known and accepted sound engineering practices. Completely resistant structures would be too expensive since "the probability that any given area of one square mile will be struck by a tornado in any given year is slight even in states where these storms are frequent. It should never be overlooked, however, that there is no assurance that any particular spot will not be struck without warning in any year, or even more than once in the same year"(2).

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(1) Massey, E.E., "Observations on the Sarnia tornado of 21 May, 1953", Defence Research Board, Ottawa. p.36.

(2) Flora, S.D., Tornadoes of the United States. University of Oklahoma Press, Norman, Oklahoma, 1953. p.4, and p.33.

(3) Factory Mutual Fire Insurance Companies. Anchorage for factory roofs: principles and design data. Inspection Dept., Boston. Loss prevention Bull. No.7,13. September 1947. 24 pp.

APPENDIX A

Damage in Rural Areas

by

D.C.Tibbetts

Enroute to Sarnia a detour was made to the Springbank area on route No. 81 to determine whether or not that area warranted any investigation on the return trip. It was decided that if time permitted an attempt would be made to trace the path of the storm through rural areas. Clean-up crews were very busy but contact was made with Mr. John McLeish.

On the return to London, after inspection of the Sarnia damage, maps of the townships immediately north and northwest of London were obtained from the district office of the Ontario Department of Highways. On May 30th, the farm of John MacNaughton, on No. 4 highway, was visited. His buildings were almost completely demolished and appeared to have been in the path of a separate tornado. The path of the main storm had crossed No. 4 highway farther north; this storm swept almost directly up the 15th concession road of London Township. Highway No. 4 was left at this intersection, and, guided by "evidence of damage", a zig-zag path was followed up the various concession roads to the farm of John McLeish. His farm was not damaged but it was not far from the church at Springbank which was in the path of the storm.

These rural areas experienced the most complete devastation; everything in the path of the storm, with the exception of silos, was practically demolished. The word "everything" includes homes, barns, out buildings, fences, and trees. There were a few exceptions, where buildings on the fringe of the storm received only minor damage, but in general, the scene was one of complete ruin. Clean-up "bees" were still active. It might be interesting to note the apparent order of priority given to the clean-up programme:

(1) Fences replaced and repaired;
(2) Stock returned to owners;
(3) Fields and crops cleared of debris;
(4) Farm buildings replaced;
(5) Homes to be completely rebuilt in most cases.

Here was a situation where not only were peoples' homes devastated but also their farmlands. In Sarnia, it was chiefly a question of homes being damaged, with some businesses being disrupted in the downtown area but, residents of Sarnia relied mainly on the heavy industries in and around that city for employment.

These industries were untouched by the storm. Rural residents however, were faced with the immediate problem of clearing fields in order to protect early crops and provide pasture and enclosure for their scattered stock.

(1) Fences

On the first visit to the area on May 27th, most fences in Springbank had been repaired to the extent that, at first glance, they appeared to have been undisturbed. Inquiries revealed, however, that on most farms in the path of the tornado, fences were either completely levelled or damaged enough to permit stock to escape easily. The repair and replacement of fences proved to be an urgent and time-consuming task for the farmers in the devastated areas. Immediately after the storm on May 21st, work was begun on this phase of the clean-up.

(2) Stock

The number of cattle and other farm animals killed, as a result of the storm, was small, but the task of separating the herds of frightened cattle scattered over the countryside and restoring them to their owners proved to be a big one. On the return trip, May 30th, people were still engaged in herding cattle back to pasture behind repaired enclosures. It was important that the cattle be kept away from the hay stored in the damaged barns. Some cattle had been injured as a result of eating hay containing splintered wood and other debris.

(3) Fields and Crops

Damage to land was extensive in the townships; debris was scattered for miles around. In addition to what was lying on the surface, large pieces of trees, metal roofing and lumber were embedded in the soil deep enough to require farm tractors or horses for their removal. This phase of the clean-up was important in order to restore pasture land for stock, clear the seeded fields, and clear the land for crops to be seeded. This clean-up was one of the major tasks. Farmers gathered with available equipment and moved methodically from field to field and farm to farm in the removal of debris. The local labour force was increased considerably by truck loads of volunteer workers from London and other nearby cities and towns.

(4) Farm Buildings

Most of the damaged barns and out buildings were old wooden structures. The roofs generally consisted of sheet metal roofing or wood shingles over 2 x 4 and 2 x 6 rafters, and were consequently of very light construction. The framing members below the roof, however, in many cases were heavy squared or hewn timbers. It would have been difficult to know how new and strongly constructed buildings would have withstood a lesser storm, so complete was the demolition of all buildings in the direct path of the tornado. Farm buildings in surrounding areas untouched by the storm, in most cases were very old and structurally weak. One newer-type barn was noted and photographed. This building had minor damage to the doors and trim but as it was not in the direct path of the storm, this damage may have been caused by the high wind accompanying the tornado. There were no buildings left standing in the direct path of the storm, so it was impossible to determine the relative merits of good and bad construction and their ability to resist tornadoes.

It was important to rebuild farm buildings as soon as possible to provide cover for crops. This left little time, because the hay crop was to be cut about six weeks after the tornado struck the area. Much work remained to be done on the land in order to complete seeding operations. Few materials could be salvaged in the reconstruction. In most instances, even the heavy, hand-hewn timbers, commonly used in old barns, were splintered and fractured beyond re-use. Here was a case in which an immediate supply of building materials would have been a great help to the farmers.

It is interesting to note that silos withstood the full force of the tornado. On farms where demolition was otherwise complete, silos were left standing and apparently unaffected by the storm. It was not determined whether or not the tops of these structures were removed by the storm. If such was the case, the possibility exists that inside and outside pressures were equalized almost immediately and thus prevented collapse. The absence of failure in these silos may also be due, wholly or in part, to their cylindrical shape.

(5) Homes

Homes in the path of the storm suffered extensive damage - in most cases, complete demolition. There were a few instances where the shell of a two-storey masonry or masonry veneer structure remained standing after the roof, windows, doors and porches had been removed by the storm, but in general, no structure stood up well under the force whether it was of wood frame, frame veneer or masonry bearing wall construction. The amount of salvageable material from demolished houses was small, being limited to brick and a few framing members. Most of the storm victims had sought shelter with neighbours. As no time could be allotted to the immediate reconstruction of dwellings, it was expected that this situation would continue for a few months until shelters could be provided for crops and stock.

Tree Damage

Some mention should be made of trees because of the vast numbers destroyed and the way in which the rural destruction differed from tree damage in the city. In Sarnia, as previously mentioned, most of the trees struck by the storm were uprooted; in the rural areas they were twisted off about 10 to 15 feet above the ground, and the tops were badly shattered and strewn over the surrounding fields. Although in both Sarnia and the rural areas, fallen trees caused an interruption of travel along traffic arteries, the heavy equipment necessary for their removal was not available in the rural areas. The farmers were forced to cut broken limbs and trunks into sizes that could be easily piled and burned or sizes that could be loaded and hauled away by farm wagons. Very few of the twisted trees could be used for saw logs or hewn barn timbers, their end use being limited to firewood. The use of farm tractors and chain saws was invaluable in clearing the pile of debris from fallen trees. More of this equipment could have been used to speed the "clean-up".

The spirit of the people in this area, their ability to organize into groups, and the "first things first" method of proceeding with the clean-up are to be highly commended. In no case was there any indication given or comment made to the effect that they were not equal to the task. As one citizen stated "All we want in order to get back to normal, are materials and tools with which to rebuild". The general opinion was that government agencies should be set up to facilitate the movement of necessary equipment and materials to disaster areas as soon as they are needed, rather than having investigations and legislation to make movement of these things possible.

APPENDIX B

PHOTOGRAPHS OF SARNIA TORNADO (May 21, 1953)

A. DBR Photographs Taken on May 28

Damage in Business District

DRM 406 ?

1.✓ Damage to roofs and parapet walls being repaired along waterfront
2. Bent flag pole in front of Vendome Hotel
3. Damaged stores along Front Street, west side. Top floors removed
4. Stores on Front Street west, under repair
5. Building on Front Street, east side, under repair
6. General view of Front Street west side under repair
7. Ballooning of wall in circular arch in condemned floor
8,9 Damage to old building of masonry bearing wall type along waterfront (note bicycle still on third floor). (Fig. 4 in DBR Report No. 111 - photo 9.)
10. Damage to buildings along waterfront
11. Remains of concrete block warehouse along waterfront
12,13 Damage to Hotel Vendome being repaired
14. General view of damage to roofs and parapet walls in business district being repaired
15. Taylor's Furniture Store and Imperial Bank
16. Imperial Bank
17,18 Taylor's Furniture Store being repaired
19. General view of damage to roofs and parapet walls under repair
20. Roof of a shed near the Capitol Theatre after collapse
21. Alley behind theatres
22. General view of roofs near Imperial Theatre
23-25 Collapsed wall behind stage of Imperial Theatre
26,27 Bell Telephone Building, steel frame construction, where little damage was done
28. Collapsed house across street from Bell Telephone Building
29. General view of damage to roof and parapet walls
30. Damaged church, although building withstood the storm it had to be condemned

Damage in Rural Areas

31. Tree Dump
32,33 Damaged automobiles
34. Knox Presbyterian Church with roof missing
35. Remains of house and other farm buildings near Knox Presbyterian Church
36. Clean-up one-half mile from church
37-39 Tree damage in London Township
40. Example of good construction. Barn in London Township that withstood the forces of the tornado. Note piece of door hanging in opening indicating that the doors acted as pressure release valves
41,42 Further examples of damage in rural area

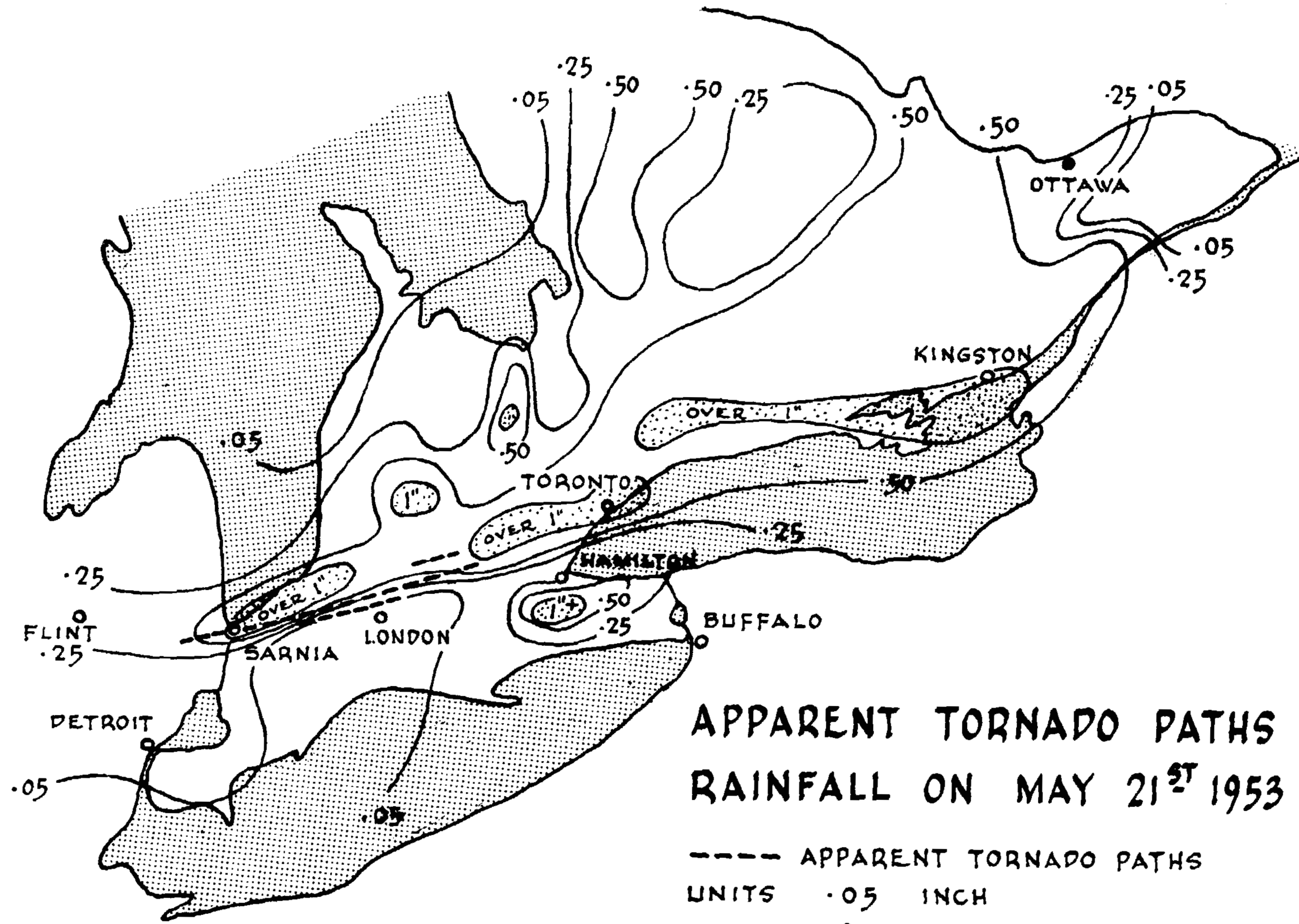
B. <u>Photographs Obtained from the Canadian Observer in Sarnia, (O) Roy Paisely, photographer, 200 London Road, Sarnia (P) and the London Free Press (S)</u>

1a. General photo of tornado at airport north of London
2a. Approximate time of storm's entry into Sarnia shown by standard clock

43. Map of Sarnia showing area affected by storm (Fig.2 in DBR Report 111)
44. Aerial view of business block in Sarnia, including Imperial Theatre
45. Aerial view of business block showing Imperial Bank and Taylor's Furniture Store. Note extensive damage to roofs caused by low pressure and centre of storm (Fig.7 in DBR Report 111)
46,47 Damage of old buildings, masonry bearing wall top along waterfront
48. Debris remaining from collapsed concrete block warehouse near waterfront
49. Debris on Front Street near Hotel Vendome
50. View across flat roofs of waterfront buildings
51-53 Front Street looking north from Hotel Vendome
54. Corner of Front and Cromwell Streets
55. Front Street. Street cleared, building repairs started (Fig.5 in DBR Report 111)
56. Hotel Vendome at the corner of Front and Cromwell Streets. Note absence of damage in braced roof.
57,58 Hotel Vendome (Fig.6 in DBR Report 111- photo 58)
59,60 Hotel Vendome. View from inside of room
61. Imperial Bank and Taylor's Furniture Store
62. Debris in street at Cromwell Street
63-67 Taylor's Furniture Store. Exposure of furniture in upper floor by complete removal of roof and collapse of one wall
68-70 Debris near Taylor's Furniture Store
71-75 Imperial Theatre. Collapse of brick wall behind stage and part of roof. (Fig.8 in DBR Report 111- photo 71)
76. Capitol Theatre. Damage to signs
77. Clean-up in progress in alley behind theatres
78. Street scene during clean-up
79. Front Street clean-up
80. Debris on street
81. Repair work in progress at Cromwell and Christina Streets
82. Damage to store window
83. Store windows after clean-up
84. Debris in driveway
85. Car damaged by falling debris
86. Debris of collapsed wood frame building
87. Debris being cleaned up
88. Repair work on four-storey structure
89,90 Street scenes
91,92 Damage in store buildings
93. Three-storey structure at Lochiel Street - little damage except to windows

94, 95 Street scene during and after clean-up at Christina and Cromwell Streets
96, 97 Bell Telephone Building. Repair work in progress near switchboards
98, 99 Debris in residential district
100. Debris and fallen trees in Lochiel Street
101-103 Tree damage
104. Debris of frame construction
105-109, 112, 122-124. Tree damage
110. Damaged crane
111. Damaged frame construction
113. Damage to frame houses. Note limited area of damage (Fig.9 in DBR Report 111)
114. Damaged roof of frame house
115. Damaged frame house
116. Completely destroyed concrete block construction (Fig.3 in DBR Report 111)
117. Repair work on frame house
118. Frame house with roof missing
119. Tree damage. Note one house with, and one house without, roof (Fig.10 in DBR Report 111)
120. Basement with missing house
121. Frame house dislocated from foundation (Fig.11 in DBR Report 111)
125. Ingenious way of using bicycle to pump gasoline at gas station during power break
126, 127 Damaged roof of church
128-131 Damage to farm buildings
132. Damage to farm buildings and trees where silo is still standing (Fig.13 in DBR Report 111)
133-136 Damage to farm homes. (Fig.12 in DBR Report 111 - photo 134)
137. Toppled hydro tower
138. Damaged brick construction
139. Damaged barn

This list includes all the photographs of the tornado in the records of the Division of Building Research. A selection from these was made for inclusion in this report.



APPARENT TORNADO PATHS & RAINFALL ON MAY 21ST 1953

---- APPARENT TORNADO PATHS

UNITS	·05	INCH
	·25	"
	·50	"
	1·00	"

BR 1224

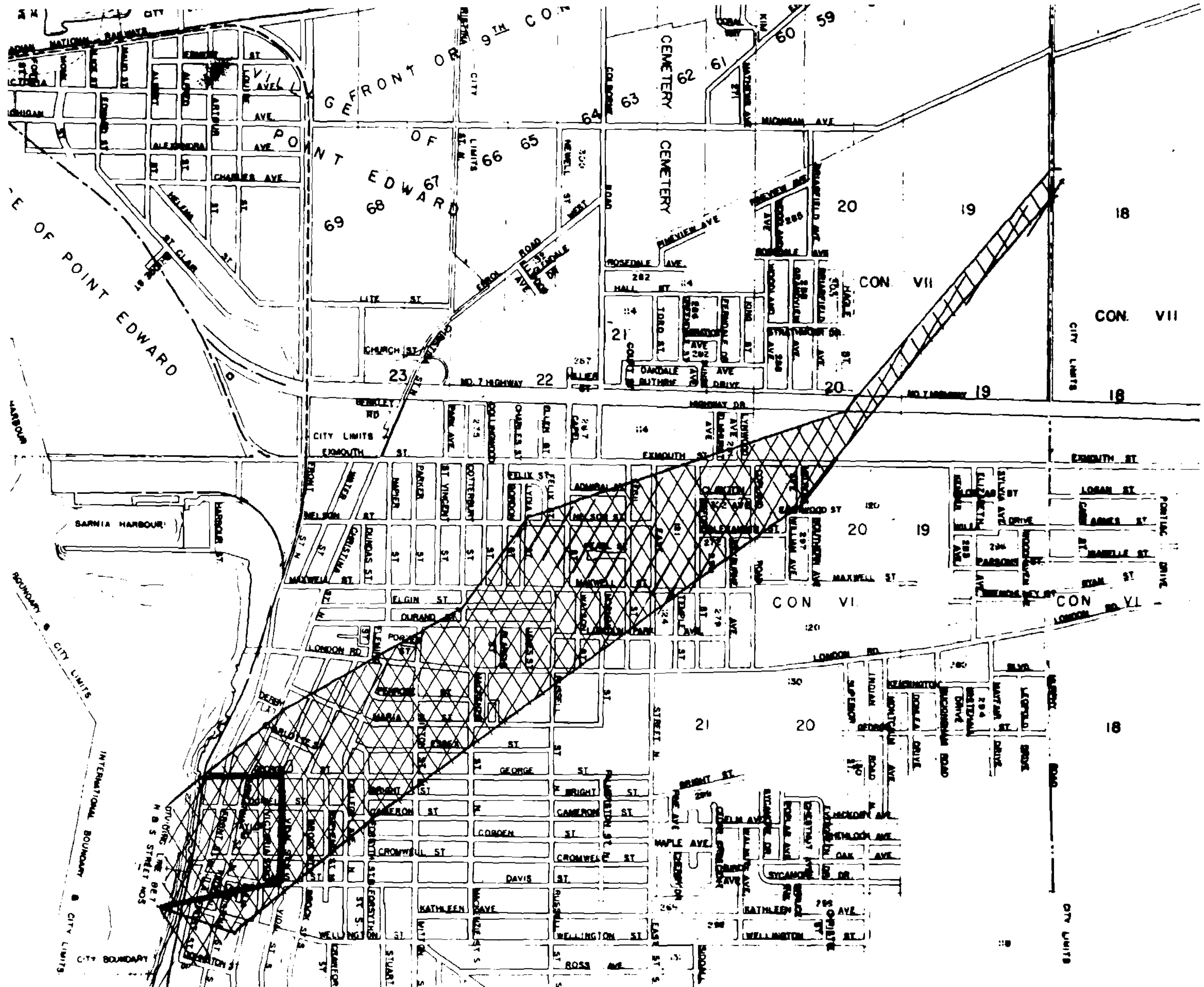


Photo by London Free Press

Figure 2 Map of Sarnia showing area affected by storm

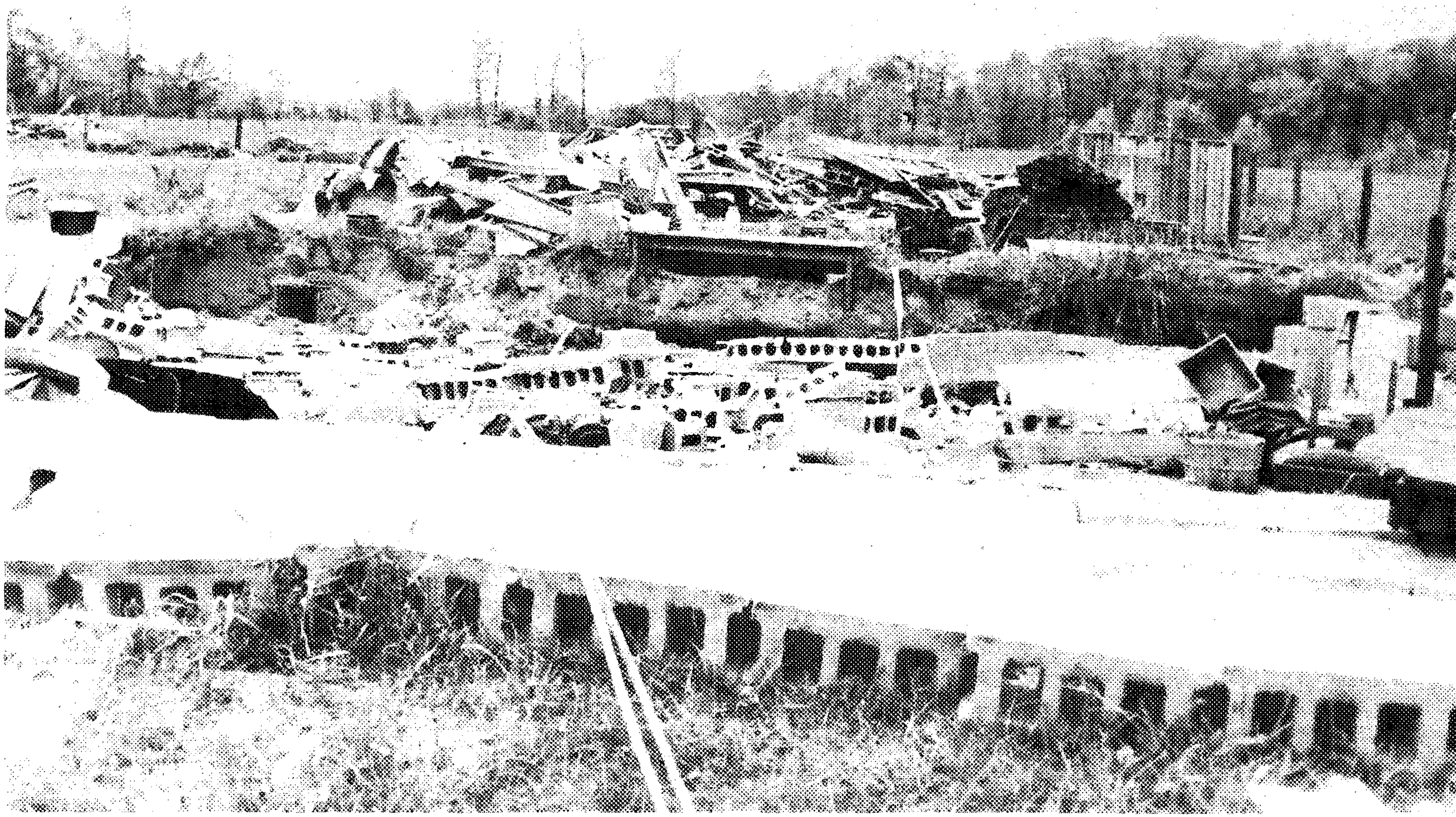


Photo by Canadian Observer, Sarnia

Figure 3 Completely destroyed concrete block construction

BR 5641

Figure 4 Damage to old building of masonry bearing wall type along waterfront (note bicycle still on third floor)

Photo by Canadian Observer, Sarnia

Figure 5 Front Street. Street cleared, building repairs started

Photo by London Free Press

Figure 6 Hotel Vendome

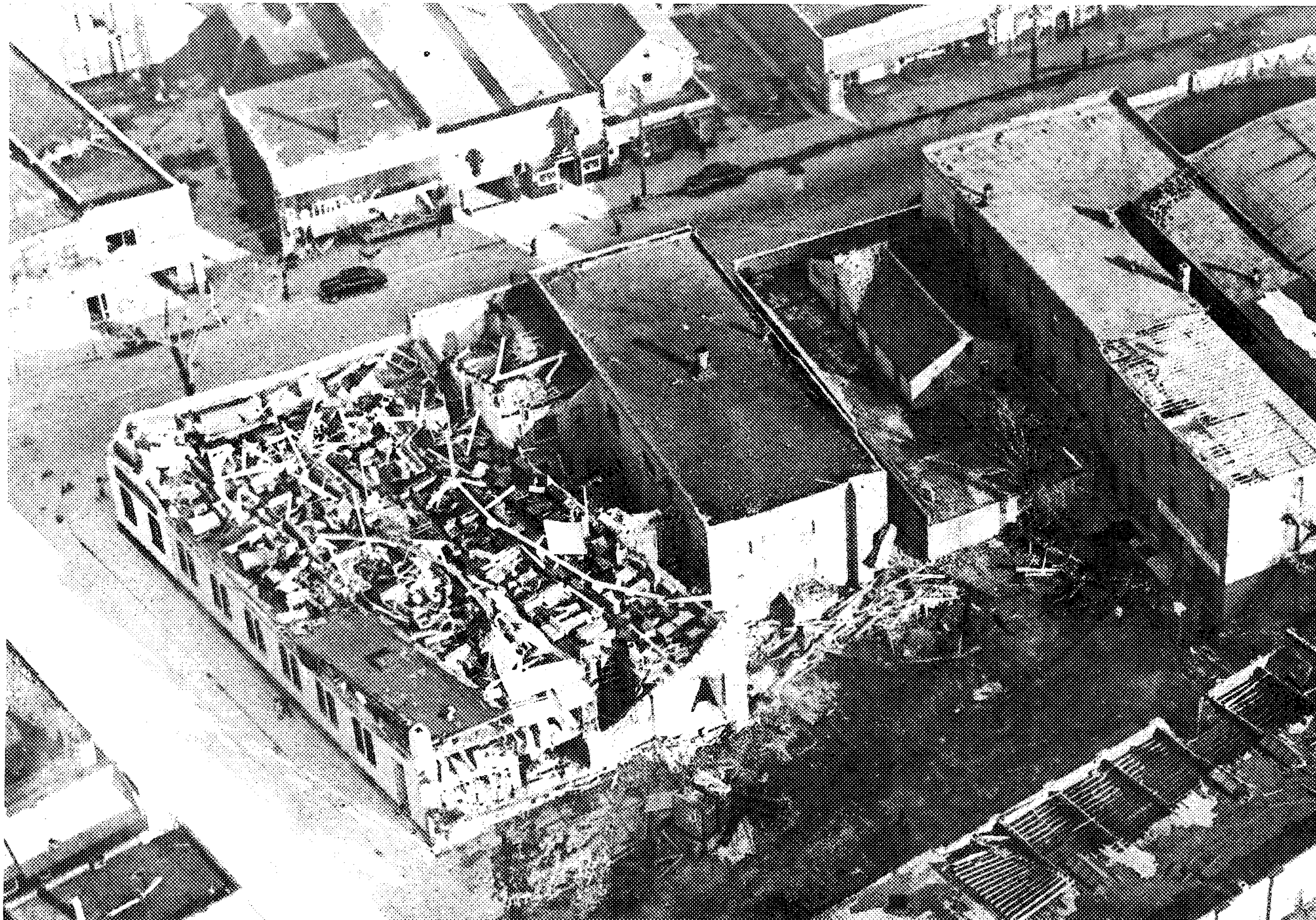


Photo by London Free Press

Figure 7 Aerial view of business block, showing Imperial Bank and Taylor's Furniture Store. Note extensive damage to roofs caused by low pressure and centre of storm

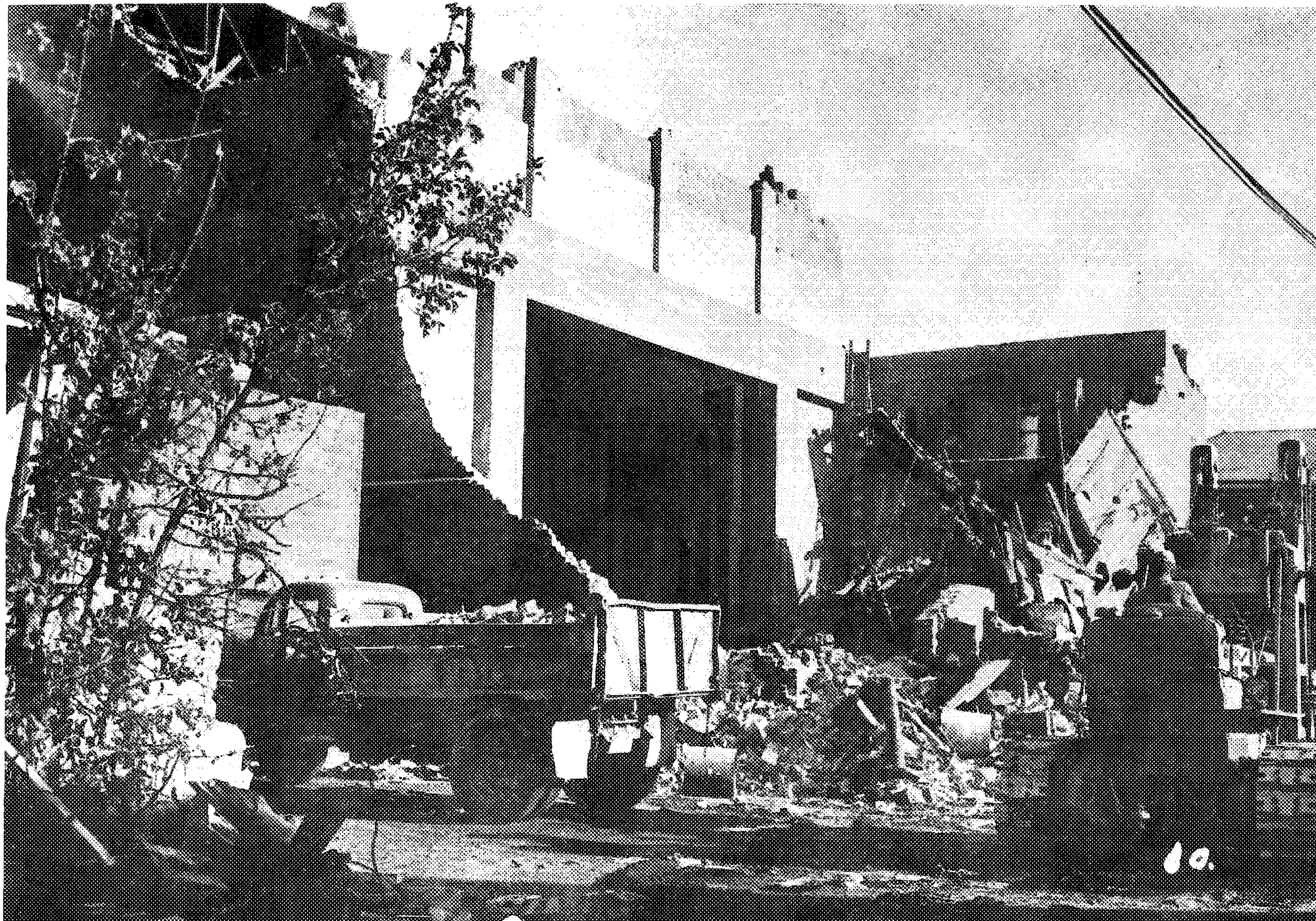


Photo by Roy Paisely, Sarnia

Figure 8 Imperial Theatre. Collapse of brick wall behind stage and part of roof.

Photo by Canadian Observer, Sarnia

Figure 9 Damage to frame houses. Note limited area of damage

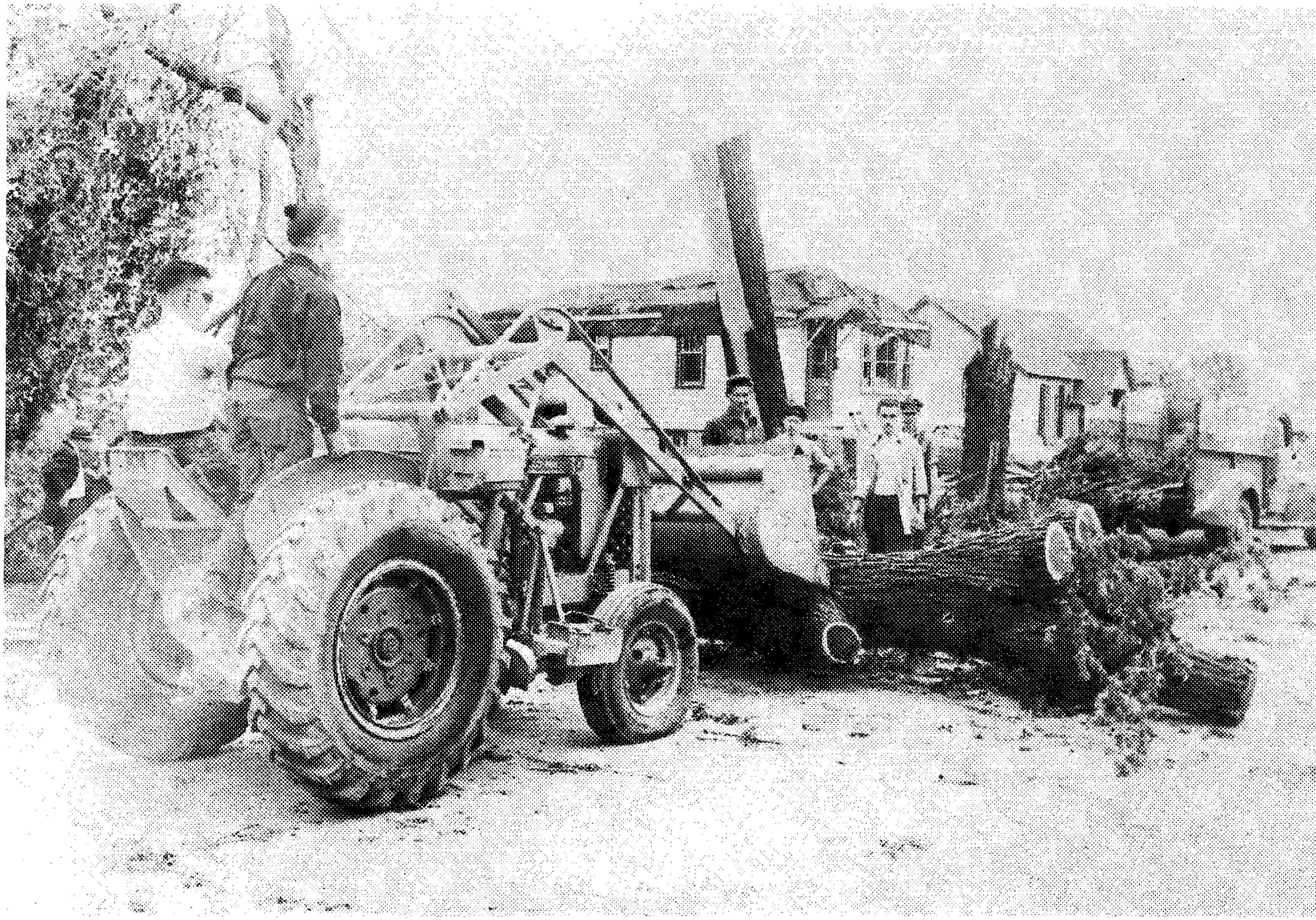


Photo by Canadian Observer, Sarnia

Figure 10 Tree damage. Note one house with, and one house without, roof

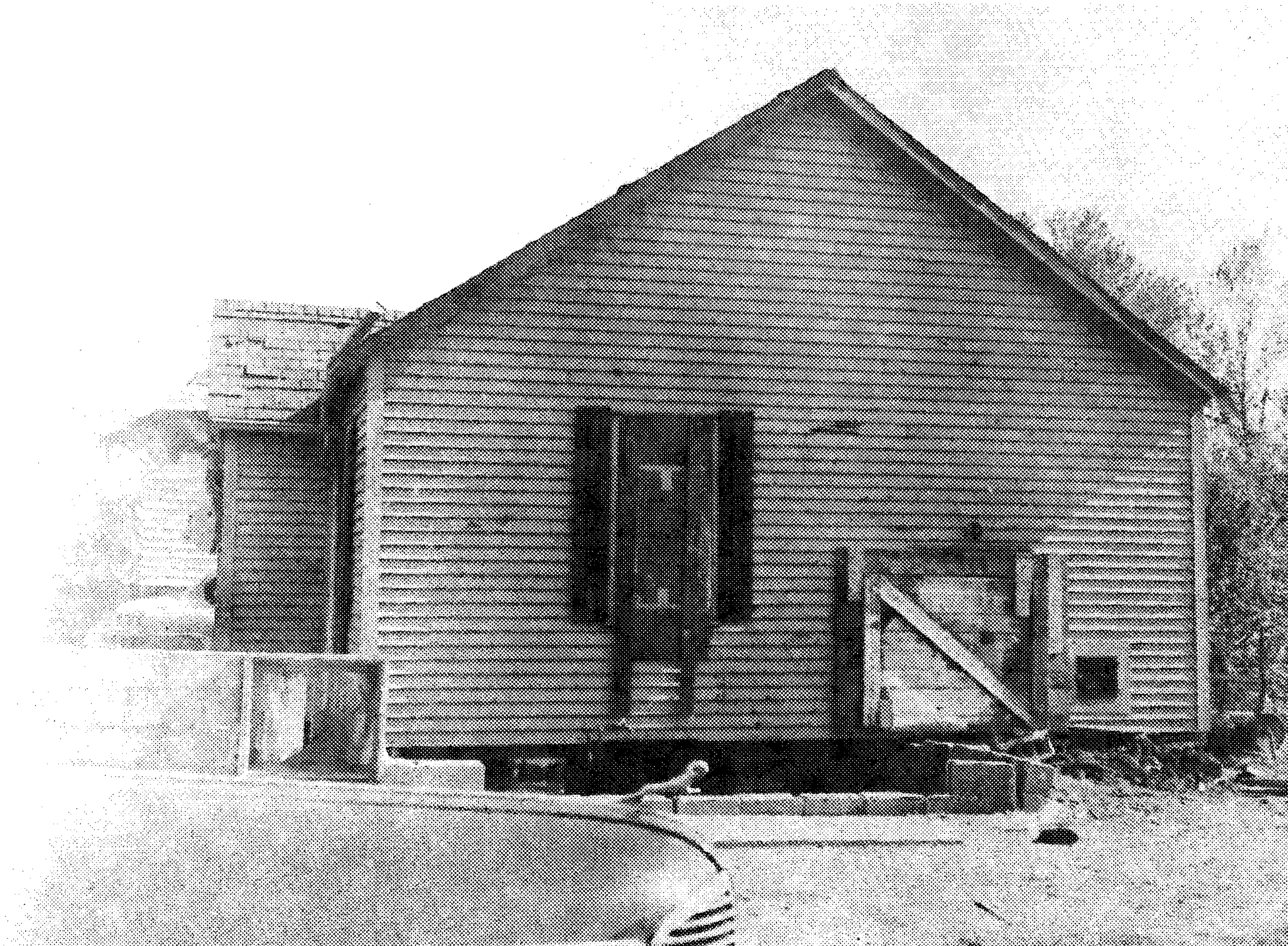


Photo by Canadian Observer, Sarnia

Figure 11 Frame house dislocated from foundation

Photo by London Free Press

Figure 12 Damage to farm homes

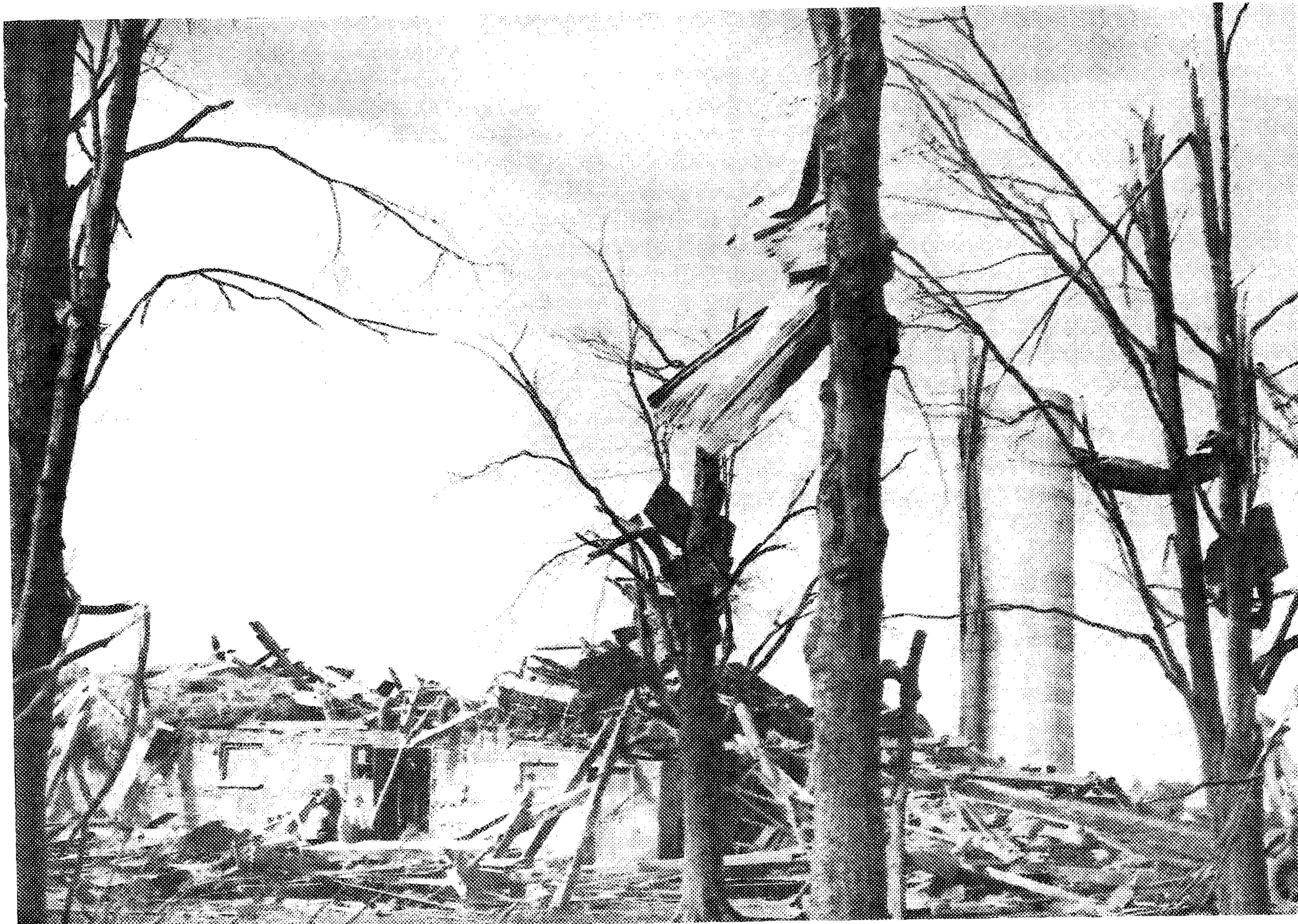


Photo by London Free Press

Figure 13 Damage to farm buildings and trees where silo is still standing