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# Transport Water Impact and Ditching Performance

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Final Report



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15. Supplementary Notes

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16. Abstract

The objective of this program was to (1) review and analyze worldwide transport accident data relative to water impacts and ditching performance, (2) compare the results of this study with current FAA requirements to determine their adequacy/relevancy, and (3) conduct a survey of major worldwide airports to determine their proximity to water. The data were analyzed with respect to the airplanes' structural integrity, breakup patterns, subsystem performance, cabin integrity, and airline procedures that were or could be contributors to injuries and fatalities. A summary of the relevant FAR's was presented to provide background for analysis of the accident data. The methods by which airframe manufacturers may certify their aircrafts' ditching behavior were presented. Because of the infrequency of unplanned water contacts and ditching (planned) occurrences, a case study approach was taken in analyzing the accident data. Eleven worldwide water impact accidents were identified between the years 1959 and 1979. Of these, only one was classified as a ditching occurrence. For the years 1980 to the present, three U.S. water related occurrences were identified with no ditching occurrences. In deep water accidents, it was found that when the flight crew had at least some degree of preparedness, trauma-caused injuries were minimized while the majority of fatalities resulted from drowning. When the impact was unexpected, however, the forces on the airplane were generally much higher, resulting in a higher proportion of injuries and fatalities caused by trauma. In shallow water incidents, usually occurring as a result of runway overruns, drowning was not as common. Injuries and fatalities in runway overruns are more likely to result from excessive localized forces caused by the airplane's impact with obstructions located in the area immediately beyond the end of the runway. A survey of transport category airports was performed to identify those airports located near significant bodies of water and to analyze the operations at these airports.

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# EXECUTIVE SUMMARY

The objective of this program was to (1) review and analyze worldwide transport accident data relative to water impacts and ditching performance, (2) compare the results of this study with current FAA requirements to determine their adequacy/relevancy, and (3) conduct a survey of major worldwide airports to determine their proximity to water. The data were analyzed with respect to the airplanes' structural integrity, breakup patterns, subsystem performance, cabin integrity, and airline procedures that were or could be contributors to injuries and fatalities. Current ditching regulations in the Federal Aviation Regulations state that a ditching is a planned event. The current methods by which airframe manufacturers certify their aircrafts' ditching behavior were presented. These methods involve the comparison of hydrodynamic characteristics with similar aircraft, scale modeling, and the evaluation of ditching accidents involving existing or comparable designs.

Because of the infrequency of unplanned water contacts and ditching (planned) occurrences, a case study approach was taken in analyzing the accident data. Eleven worldwide water impact accidents were identified between the years 1959 and 1979. Of these, only one was classified as a ditching occurrence. For the years 1980 to the present, three U.S. water related occurrences were identified. There were no ditching occurrences identified during these years. All three occurrences involved runway overruns.

In deep water accidents, it was found that when the flight crew had at least some degree of preparedness, trauma-caused injuries were minimized while the majority of fatalities resulted from drowning. When the impact was unexpected, however, the forces on the airplane were generally much higher, resulting in a higher proportion of injuries and fatalities caused by trauma. In shallow water incidents, usually occurring as a result of runway overruns, drowning was not as common. Injuries and fatalities in runway overruns are more likely to result from excessive localized forces caused by the airplane's impact with obstructions located in the area immediately beyond the end of the runway. These localized forces were concentrated at the nose section of the airplane and often led to fuselage breaks and separations.

A survey of worldwide transport category airports was performed to identify those airports located near significant bodies of water and to analyze the operations at these airports. The airport database consisted of 156 U.S. airports which serve as large, medium, or small hubs for transport flights, as well as 100 foreign airports which provide international service.

## 1. INTRODUCTION.

With the number of overwater operations rising, the potential for water impact increases. Factors such as hydrodynamic pressure on the aircraft fuselage, the aircraft flotation properties, passenger flotation equipment, and occupant evacuation time are important aspects of the total aircraft design that overwater performance regulations should address.

This study examines water impact accidents that occurred between 1959 and 1991. Data were examined to investigate structural features, fuselage breakup patterns, subsystem failures, and cabin interiors as they related to injuries and fatalities. The interaction between passengers and their surroundings was also examined.

For the years 1959 to 1979, accident data were collected from previous transport airplane accident studies performed by the three main U.S. airframe manufacturers, Boeing, Lockheed, and McDonnell Douglas (references 1, 2, and 3). Reports involving water impacts (references 4, 5, and 6) were obtained from the National Transportation Safety Board (NTSB) for those accidents occurring between 1980 and 1991. Each accident was analyzed and put into a case study format to permit a thorough examination of the mishap.

Currently, aviation regulations regarding aircraft ditching are based on the premise that water impact mishaps occur a significant distance from the airport. Because it has been found that the majority of aircraft accidents occur in close proximity to the airport (reference 7), particularly during the approach and departure phases of flight, a survey of transport category airports was performed to identify those located near significant bodies of water and to analyze the operations at these airports. An airport database was generated using data obtained from the FAA's annual Airport Activity Statistics of Certified Route Air Carriers publication (reference 8) and International Civil Aviation Organization (ICAO) Digest of Statistics, Airport Traffic publication. The database consisted of 156 U.S. airports which serve as large, medium, or small hubs for transport flights and 100 foreign airports which provide international service. The airport operations figures were obtained from the FAA and ICAO publications, and the surrounding bodies of water were identified using U.S. Terminal Procedure approach plates and DoD Flight Information Publications published by the National Oceanic and Atmospheric Administration (references 9 and 10).

## 2. BACKGROUND.

This section presents a summary of the relevant Federal Aviation Regulations (FAR's) and the methods by which aircraft manufacturers substantiate that their aircraft adhere to these regulations. A discussion of the definition of ditching is presented to differentiate planned from unplanned water contacts.

### 2.1 DITCHING VERSUS UNPLANNED WATER CONTACT.

Transport aircraft water impacts are classified into two basic categories: ditching (planned) and unplanned water contact.

A ditching is an emergency landing in water, i.e., planned water contact. For an official "ditching" to occur, certain impact parameters must be present. The descent rate cannot be greater than 5 ft/sec, and the longitudinal and vertical loads must be within aircraft design parameters (reference 11). When proper ditching procedures are followed, the occupants should have several minutes to prepare for the impact, which is typically less severe than an unplanned impact because the pilot maintains substantial control of the aircraft. For these reasons, occupants are more likely to survive a ditching rather than an unplanned water impact. Although proper preparation does not guarantee survival, it may increase it because the cabin crew can assist the occupants in preparing physically and mentally for the touchdown. If the occupants know that an impact is imminent, they will be more likely to make use of personal flotation and other safety equipment. They also have time to locate the closest emergency exit and review proper evacuation procedures.

The recommended procedure for an emergency landing on water generally contains the following:

a. If possible, a reduction in weight should be attempted since this would reduce the landing speed.

b. Maximum flaps should be utilized to reduce touchdown speed to a minimum.

c. The final rate of descent should be kept as low as possible.

d. At touchdown, the aircraft should be in a specified noseup attitude. Generally this attitude is between 10 and 14 degrees.

e. The final approach should be made with the aircraft straight and level, with roll correction and yaw angles below 10 degrees.

f. The undercarriage should be retracted if possible.

g. If a pronounced sea is present, the landing should be made parallel to, and not across, the line of the wave crests. If possible the touchdown point should be on the crest or the back side of the wave.

The recommended procedures are then incorporated into the airplane's Cabin Crew Manual of Emergency procedures.

Generally, an unplanned water impact involves higher aircraft velocities, forces, and damage, resulting in more severe injury levels. There is little, if any, time for occupants to prepare for the impact. It is possible that seatbelts may not be fastened and crash positions may not be assumed. Substantial damage to the fuselage usually occurs. The damage may reduce the flotation performance of the aircraft, thereby reducing the aircraft's time afloat and the probability of successful passenger egress.

## 2.2 RELEVANT FEDERAL AVIATION REGULATIONS.

The FAA has several regulations that transport aircraft must satisfy if they are to be certified for extended overwater operations. These regulations include design guidelines, equipment requirements, and evacuation procedures which are intended to allow maximum passenger survivability. A complete list of relevant ditching regulations is included in appendix A.

The current FAR's which specifically discuss overwater emergency scenarios are based on the premise that the water contact will be a planned event. The FAR's contain requirements for emergency exits, equipment, and the demonstration of occupant evacuation capabilities. They also address aircraft water impact behavior by stating requirements for fuselage buoyancy, flotation time, and aircraft trim with respect to the local sea conditions which are likely to occur. The emergency flotation equipment required for aircraft depends on whether the aircraft is going to be certified for "extended overwater" operations (i.e., aircraft operations which are more than 50 nautical miles offshore) or for normal operations. Normal operations require individual flotation devices for each occupant while the former requires additional equipment such as lifevests, survivor locator lights, and life rafts.

Aircraft manufacturers must be able to demonstrate, through either model testing or comparison with similar aircraft models, the behavior of aircraft in a ditching situation. Drills must be conducted in order to demonstrate the emergency evacuation procedures.

## 2.3 DITCHING/FLOTATION SUBSTANTIATION.

The landing of an airplane on water is an emergency measure that an aircraft makes only once. Loss of the aircraft is acceptable, provided the crew and passengers can safely escape and be rescued. For a water contact to qualify as a ditching, it is necessary that the touchdown follow a prudent approach and acceptable procedures. The design must

a. provide structural integrity to protect the crew,
b. ensure that no excessive decelerations will be experienced by the occupants, and
c. provide sufficient time for safe egress from a damaged aircraft.

The methods by which aircraft manufacturers may show compliance with FAR 25 Ditching Requirements are

a. comparison of hydrodynamic characteristics such as fuselage shape, size, and available buoyancy with previous designs;

b. scale model tests to demonstrate ditching performance and evaluate design strengths for fuselage skin, doors, and bulkheads; and

c. evaluation of ditching accidents involving existing or comparable designs.

To substantiate the ditching/flotation characteristics, the manufacturer may provide a combination of scale model tests, analysis, comparison with previous designs and/or accident data.

2.3.1 Ditching Compliance.

The manufacturer may emphasize design comparison and/or scale model tests to substantiate ditching compliance. Each of these areas will be discussed to show their application to the ditching certification process.

2.3.1.1 Comparison to Similar Aircraft.

The manufacturer may demonstrate compliance by showing that the design is similar in both geometry and size to existing designs which have already demonstrated satisfactory hydrodynamic behavior. For example, an aircraft with a wider wing span than the previous configuration would be expected to provide additional buoyancy which would be beneficial for flotation. As long as the shapes are the same, differences in fuselage length alone would normally not be sufficient to cause any significant ditching behavior changes.

The design features of an airplane are important in establishing a qualitative assessment of ditching behavior. For example, the manufacturer would attempt to show that the design characteristics of the wing are beneficial to ditching and flotation.

Wing design characteristics such as low position, large surface area, and low wing loading will provide buoyancy and bear a portion of the impact load with the fuselage.

Scale model testing has shown that

a. the most favorable wing position is slightly above the bottom of the fuselage,

b. the thickness and size have little effect on ditching,

c. a low wing design provides the benefit of an additional planing surface,

d. impact pressures are localized on the centerline and decrease toward the side for round-bottom fuselages,

e. sharply curved fuselages do not provide resistance to downward pitching moments caused by damage at impact, and

f. an aft fuselage that is sharply curved is subject to considerable suction forces, which can cause the tail to suck down, resulting in a sudden noseup trim, followed by a subsequent severe nosedown impact.

Fuselage shape design considerations such as a rounded bottom that is moderately curved lengthwise is expected to produce lower impact pressures, mean pressure and force versus that of a flat bottom and thus have good ditching characteristics. A relatively high ratio (4:1) of nose length to height of c.g. above the bottom of fuselage will tend to show good resistance to diving.

2.3.1.2 Scale Model Tests.

The use of scale model airplane tests to demonstrate ditching characteristics is not common for the certification of newer aircraft. The expense of performing such a test is costly and frequently the newer designs are derivatives of a previously certified configurations. The test of a 1/17th scale model of the L-1011-1 in 1970 may have been the last such test for a modern airplane. Such a test program would be designed to (1) perform a series of tests to assess probable ditching characteristics, (2) demonstrate the capability of the airplane to make a safe emergency landing under a range of landing conditions on calm water and in beam (lateral) seas, and (3) recommend a procedure for the ditching of the airplane.

A scale model test program would investigate among other things

a. a calm sea and sea state ( regular beam (lateral) and head wave) landings;
b. a range of landing weights and touchdown attitudes and speeds;
c. the effects of pitch, roll, yaw, and rates of descent;
d. the effects, if any, of component failure;
e. the effects of a retracted or extended undercarriage at various approach speeds;
f. determination of static flotation waterline at various weights and c.g.'s; and
g. the determination of weather cocking behavior in calm water and other sea states.

Various fuselage accelerations would be measured, along with underside and bulkhead pressures. Shear forces and bending moments would be measured. The pressures, loads, and accelerations would be used to assess the structural integrity of the airframe, doors, and bulkheads, particularly with regard to design requirements. The fuselage is generally designed to a static pressure distribution.

2.3.2 Flotation Behavior.

In addition to comparisons with previous certified designs, the manufacturer may be required to demonstrate the specific flotation characteristics of the new design. Analysis may be used to show, for various c.g. configurations and flooding conditions, the position of the exits relative to the waterline and the length of time each exit remains above water. Both static and dynamic flotation analysis may be conducted.

2.3.2.1 Static Analysis.

The flotation behavior of an airplane begins with a layout of the airplane depicting the pressurized areas. When the airplane first rests in the water, buoyancy is primarily provided by the volume of water displaced by the submerged portion of the fuselage. The weight of the aircraft and its c.g. location will influence the attitude of the aircraft in the static flotation position. The airplane weight and c.g. design envelope varies according to the loading conditions, i.e., maximum landing or maximum takeoff gross weight. Typically a static analysis is performed for the maximum design landing weight condition. It is assumed that the pilot can jettison fuel to minimize the impact loads for a ditching. The weight/buoyancy ratio will influence the flotation equilibrium position. As a result of the flotation analysis a determination is made of the airplane attitude and the height that the various exit doors are above the waterline as the airplane sits in the water with no loss of buoyancy. Typically this is shown for several conditions such as

a. no flooding, forward c.g.;
b. no flooding, aft c.g.; and
c. cargo compartments flooded, aft c.g.

2.3.2.2 Dynamic Analysis.

A dynamic flotation study may be conducted to determine how the airplane changes position as flooding progresses. To perform this analysis the structural damage sustained during the impact must be ascertained. Normally this would consist of loss of flaps, engines, and the tail of the aircraft, and possibly damage to the underside or cargo door that could result in leakage of water into the pressurized regions with subsequent loss of buoyancy. Of interest in this analysis is the time it takes to reach an equilibrium position and whether one or more of the exits are not accessible for egress. If such a condition would be found to exist then the Emergency Procedures Manual would reflect it.

A dynamic flotation analysis would involve the following steps:

a. The static flotation airplane position is used as a starting point.

b. A determination of loss-of-buoyancy regions which would result in leakage into otherwise pressurized compartments.

c. A determination of pressure heads, leakage areas, and flow rates.

d. A time-dependent algorithm used to predict the airplane weight, c.g., and attitude, as well as exit door position relative to the water level until equilibrium is reached.

## 3. REVIEW OF ACCIDENT DATA FOR 1959-1979.

A great deal of research has been conducted on transport aircraft accidents which occurred during the years 1959 to 1979 (references 1, 2, and 3). The U.S. Federal Aviation Administration summarized the data 1959-79 which pertained to water impact accidents in "Study On Transport Airplane Unplanned Water Contact" (reference 12). The data were collected from various domestic and international sources including the Civil Aeronautics Board (CAB), National Transportation Safety Board, foreign governments, airlines, and aircraft manufacturers. Nine hundred and thirty-three transport ground/water accidents were reviewed. These were then reduced to 153 accidents by imposing criteria on occupant survivability and aircraft crashworthiness. Of these 153 accidents, water was involved in 16 cases. Water was found to be a significant factor in only 11 of these cases. Of these, only one was classified as a ditching occurrence. This smaller database of 11 cases is reviewed here relative to occupant survivability, hazards to occupant survivability, and structural damage. Summary information for these 11 cases is presented in table 1.

TABLE 1. WATER IMPACT ACCIDENTS FROM 1959-1979

| Accident | Year | Hull Loss | On-Board | Fatal-ities | Serious Injuries | Flight Phase | Fire | Occupant Survivability[1] |
|---|---|---|---|---|---|---|---|---|
| 092461 720 Boston | 1961 | NO | 71 | 0 | 2 | LDG | YES | YES |
| 082062 DC8 Rio De Janiero | 1962 | YES | 105 | 15 | NA | T/O | NO | YES |
| 040764 707 JFK | 1964 | YES | 145 | 0 | 7 | LDG | NO | YES |
| 063067 CVL Hong Kong | 1967 | YES | 80 | 17 | 5 | APP | NO | YES |
| 110567 880 Hong Kong | 1967 | YES | 137 | 1 | NA | T/O | NO | YES |
| 011369 DC8 Los Angeles | 1969 | YES | 45 | 15 | 17 | APP | NO | YES |
| 050270 DC9 St. Croix, V.I. | 1970 | YES | 63 | 25 | 25 | LDG | NO | PARTIALLY |
| 072770 DC8 Naha, Okinawa | 1970 | YES | 4 | 4 | 0 | APP | NO | PARTIALLY |
| 121877 CVL Madeira, Spain | 1977 | YES | 57 | 36 | 13 | LDG | NO | YES |
| 050878 727 Pensacola | 1978 | YES | 58 | 31 | 1 | APP | NO | YES |
| 122378 DC9 Palermo, Italy | 1978 | YES | 129 | 108 | NA | LDG | NO | UNKNOWN |

[1] For an accident to be classified as "survivable," it must meet all of the following criteria (reference 11):

a. There must exist a livable volume within the airframe during and after impact and prior to severe fire.
b. At least one occupant must not die from trauma.
c. There must exist a potential for occupant egress.
d. The impact forces must be within human tolerances.

## 3.1 OCCUPANT SURVIVABILITY/HAZARDS TO SURVIVABILITY

The 11 accidents were first divided into two groups: high energy impact and slide/roll into water. The accidents were then further subdivided into two crash scenarios: lower fuselage crush and fuselage break. Table 2 summarizes the structural damage associated with these 11 accidents.

TABLE 2. STRUCTURAL DAMAGE SUMMARY 1959-1979

| Accident Group | No. of Accidents | Hull Loss | Tank Rupture | Floor Displacement | Exit Door Damage | Seat Dislocation | Cabin Interior Damage | Fuel Line Damage |
|---|---|---|---|---|---|---|---|---|
| High Energy | 8 | 8 | 5 | 6 | 7 | 5 | 6 | 1 |
| Lower Fuselage Crush | 2 | 2 | 1 | 2 | 2 | 2 | 2 | 1 |
| Fuselage Break | 6 | 6 | 4 | 4 | 5 | 3 | 4 | 0 |
| Slide/Roll | 3 | 0 | 1 | 1 | 3 | 2 | 1 | 0 |
| Lower Fuselage Crush | 2 | 0 | 1 | 1 | 2 | 1 | 0 | 0 |
| Fuselage Break | 1 | 0 | 0 | 0 | 1 | 1 | 1 | 0 |

Table 3 summarizes the water impact fatalities and their causes for the same eleven accidents. The predominant cause of fatalities was drowning, which accounted for 98 percent of the fatalities in these two crash scenarios. The remaining fatalities were caused by trauma resulting from inertial forces due to high accelerations or impact with the occupant's surroundings.

TABLE 3. ACCIDENT FATALITY SUMMARY 1959-1979

| Accident Group | Occupants | Fatalities | Percent Occupant Fatality | Trauma | Percent Occupant Fatality | Drowned | Percent Occupant Fatality |
|---|---|---|---|---|---|---|---|
| High Energy | 507 | 206 | 40.6 | 4 | 0.79 | 202 | 39.8 |
| Slide/Roll | 387 | 16 | 4.1 | 1 | 0.26 | 15 | 3.9 |

The majority of the drowning fatalities occurred in accidents where the aircraft came to rest in deep water. Six such accidents involved fuselage breaks, resulting in a rapid sink rate and a 36.8 percent fatality rate from drowning. There were also four deep water accidents in which the fuselage did not break, with a reduced fatality rate of 25.9 percent. In addition, these aircraft were able to float for at least 5 minutes, and in most cases 10 to 20 minutes, allowing more time for evacuation. However, in three of these four accidents, the emergency onboard rafts and float slides were not used. Improper crew actions after the aircraft came to rest were found to contribute to at least 15 reported drownings which occurred after evacuation. Other factors which contributed to the high fatality rates were reports of carryon luggage blocking the emergency exits, jamming of emergency exit doors, and displacement of the passenger compartment floor.

## 3.2 STRUCTURAL DAMAGE.

The structural damage discussed here includes fuselage breaks, fuselage lower surface crush, passenger compartment floor displacements, and seat dislocations.

Fuselage breaks occurred in 6 of the 8 high-energy water impact accidents, leading to a fatality rate of 36.8 percent. Five of these six fuselage breaks led to a high sink rate of at least a portion of the aircraft fuselage. Fuselage breaks also led to the rupture of fuel lines which exposed the passengers to the hazard of chemical burns and made exposed surfaces extremely slippery, further hampering evacuation efforts. For those accidents in which the aircraft slid/rolled into the water, only one involved a fuselage break, and this resulted in no fatalities. Seat dislocations also result from fuselage breaks, as highly localized accelerative pulses are generated in the vicinity of the break. This increases the risk of injury as the seat occupant is no longer decelerating with the aircraft and can come into forcible contact with the surrounding structures (reference 1). Four of the water impact accidents in which fuselage breaks occurred also resulted in seat elevations or dislocations.

Of the four accidents with lower fuselage crush, three had extensive damage to the lower surface. In these three accidents, the aircraft came to rest in deep water and there were 41 fatalities (18.1 percent of total on board). An example of such a case is the Boeing 727 Pensacola accident. This accident resulted in water impact forces which destroyed the lower fuselage, ruptured the body fuel lines, and separated the engine. The fourth accident involving lower surface crush resulted in the aircraft coming to rest on its landing gear in shallow water thus there was limited damage. No fatalities resulted in this case.

Displacement of the passenger compartment floor can result from the hydraulic action of water when an aircraft lands on water or rolls into water at high speeds. This may result in the jamming of exit doors, movement of debris throughout the cabin, and seat displacement and dislocation, all of which violate the aircraft's occupiable space and will, at the very least, result in the impedance of passenger egress. Seven water impact accidents involved such floor displacements, three of which resulted from lower surface ruptures which allowed water to fill the cargo compartment. Two of these seven accidents involved seat dislocations, three involved seat elevations, and two involved the blockage of exits.

## 3.3 SUMMARY OF ACCIDENT DATA FOR 1959-1979.

Numerous recommendations have been made to improve the survivability of water impact accidents. Most address improvements to the quality and accessibility of onboard flotation devices. The review of the 1959-1979 data shows that the majority of the fatalities resulted from a lack of time to secure and don flotation devices after water impacts. The study (reference 12) concluded that unplanned water contacts usually result in flooding conditions which adversely affect the occupants' ability to locate, deploy, and/or don emergency flotation equipment. It cannot be expected that an unplanned water impact will result in no lower surface crush and no flooding conditions. Accordingly, the study also concluded that under such conditions as flooding and/or a sinking fuselage, the successful use of emergency flotation devices is dependent on the occupants' ability to quickly locate, deploy, and/or don these devices (reference 12).

After reviewing the studies, it is difficult to base conclusions on ditchings alone because they are very rare. Although current procedures and equipment designs are based on the assumption that transport aircraft water impacts are primarily ditchings during "extended overwater flights" (reference 13), the more common occurrence is the uncontrolled, high-energy impact in proximity to the airport. These high-energy water impacts generally lead to either one or more fuselage breaks or lower surface crush. Both damage types result in most aircraft sinking and therefore a high fatality rate due to drowning.

# 4. REVIEW OF ACCIDENT DATA FOR 1980-1991.

Several sources were used to obtain accident data for 1980 to 1991, including NTSB, the Civil Aviation Administration (CAA), the International Civil Aviation Organization (ICAO), and Canadian Aviation Safety Board (CASB). From all accidents, water-related accidents were identified. Only the NTSB was able to provide full accident reports. A listing of the non-NTSB water-related international accident data is presented in table 4. Case studies of the water-related accident data obtained from the NTSB were conducted.

TABLE 4. SUPPLEMENTAL ACCIDENT DATA 1980-1991

| Date | Aircraft Model | Accident Location | Total On Board | Fatalities | Accident Description |
|---|---|---|---|---|---|
| 8/7/80 | TU-154 | Mauritania | 168 | 2 | Aircraft crashed into sea 300 meters short of runway during final approach. |
| 9/12/80 | B727 | Corfu Airport | 115 | 0 | Main landing gear detached on landing; aircraft came to rest with nose in water. |
| 5/7/81 | BAC1-11 | Argentina | 30 | 30 | Crashed in river in bad weather during attempted landing. |
| 2/9/82 | DC8 | Tokyo | 174 | 24 | Mentally unstable pilot; aircraft plunged 550 meters short of runway. |
| 9/10/82 | B707 | Khartoum | 11 | 0 | Crashed in Nile River three miles short of runway. |
| 8/4/84 | BAC1-11 | Philippines | 80 | 0 | Overran runway on landing; aircraft came to rest in sea. |
| 6/23/85 | B747 | Ireland | 325 | 325 | Plane disappeared from radar 150 miles north of Ireland and crashed in Atlantic Ocean. |
| 6/27/85 | DC-10 | San Juan | 270 | 0 | Aborted takeoff and nose came to rest in lagoon. |
| 2/16/86 | B737 | Taiwan | 13 | 13 | Contact lost 3.5 miles after go around and presumed to have crashed at sea. |
| 8/31/87 | B737 | Phuket | 83 | 83 | Plane dove into sea while avoiding second B737 during approach. |
| 11/28/87 | B747 | Mauritius | 159 | 159 | Fire on board; aircraft crashed in 15,000 ft. of water; scattered debris. |
| 8/31/88 | Trident | Hong Kong | 89 | 7 | Aircraft hit approach lights during approach and came to rest in bay. |
| 9/26/88 | B737 | Argentina | 62 | 0 | Aircraft landed with excessive speed and came to rest partially submerged in sea. |
| 9/11/90 | B727 | North Atlantic | 18 | 18 | Contact was lost following fuel problem distress call; wreckage not located. |
| 2/20/91 | BAe146 | Chile | 72 | 20 | Aircraft overran runway during landing and came to rest partially submerged. |

In the following sections, three of the water-related accidents were reviewed as they pertain to occupant injury, structural damage, subsystem participation, emergency equipment performance, airport rescue procedures, and airport proximity to water.

## 4.1 AIRCRAFT ACCIDENT REPORT - WORLD AIRWAYS, INC., FLIGHT 30H, MCDONNELL DOUGLAS DC-10-30CF, N113WA, BOSTON-LOGAN INTERNATIONAL AIRPORT, BOSTON, MASSACHUSETTS, JANUARY 23, 1982.

### 4.1.1 Accident Brief.

On January 23, 1982, World Airways, Inc., Flight 30H, a McDonnell Douglas DC-10-30CF was enroute to Boston-Logan International Airport in Boston, Massachusetts. Following a nonprecision instrument approach, the airplane touched down approximately 2,800 feet beyond the usable part of the runway. The airplane veered as it approached the departure end of the runway to avoid the approach light pier and slid into the shallow water of the Boston Harbor. The surface of the runway was covered with hard packed snow and glaze ice overlaid with rainwater. The accident occurred in darkness with light rain and fog and resulted in injuries to seven crewmembers, twenty-one passengers, and two rescue personnel. Two of the 200 passengers were presumed dead as their bodies were never recovered.

### 4.1.2 Structural Damage.

Upon crossing the end of the runway, the airplane came to rest with a slightly nosedown attitude in water which came up to the wings. A section of the nose up to the first row of the cabin seats separated along a fracture line (figure 1) and remained attached to the fuselage only by control cables and electric wire bundles. The pressure bulkhead was crushed along the fuselage bottom centerline, and the main cabin floor beams from fuselage station (FS) 392 to 475 failed due to the downward displacement. The pressure bulkhead at the forward end of the nose gear was crushed as well, leading to the failure of the extended nose gear. The main landing gear were extended and remained undamaged. The airplane's three engines remained attached to their respective pylons, although the No. 3 engine's rear mount was broken. There was no substantial mechanical damage to the engine.

The accident was survivable. With the exception of the area surrounding the first passenger row, the decelerative forces experienced by the passengers did not exceed the known tolerance limits of the human body, the seats and restraint systems remained intact, and the occupiable space on the aircraft was not violated.

### 4.1.3 Subsystem Participation.

The overall impact forces experienced by the passengers as the aircraft came to rest in the water did not jeopardize occupant survival except in the area of the fuselage separation. The failure of the main cabin floor beams in this area led to floor displacement and subsequent seat track fractures. Three seat modules in the first passenger row, consisting of three left, two center, and three right seats, separated from the floor. This led to the disappearance and presumed death of two of the three passengers seated in this row. The third passenger seated in this row was able to climb back into the main cabin. The cabin aft of the structural separation remained intact.

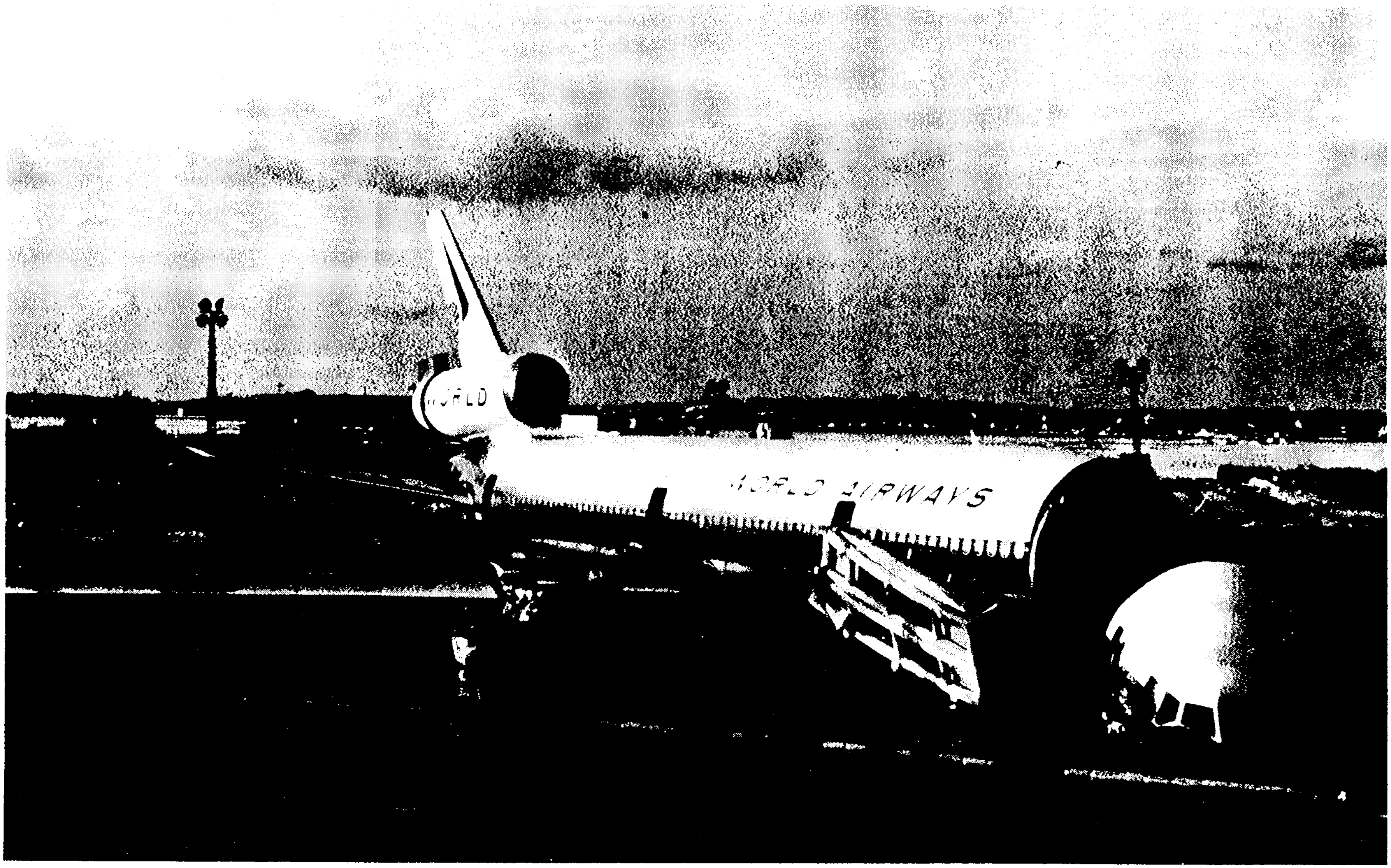


FIGURE 1. WORLD AIRWAYS DC-10 AFTER COMING TO REST IN BOSTON HARBOR

The airplane was equipped with eight floor level exits, L1-L4 and R1-R4 (figure C-2); L-3 and R-3 are both overwing exits. All exit doors, with the exception of the two foremost exits which separated with the nose section, opened easily and the slide/rafts deployed successfully. The left rear exit, L4 was unusable due to the centerline engine thrust reverser continuing to blow and thereby forcing the slide/raft against the fuselage. There were difficulties in exiting through R-4 and L-2 as well, as the airflow created by the centerline thrust reverser twisted the slide/rafts. While the majority of passengers left through the R-3 overwing exit and slide/raft, approximately 30 passengers used the R-4 exit. The captain and a few passengers used the left overwing exit.

With the exception of the immediate area surrounding the fuselage separation, the cabin contents and furnishings remained in place and did not hamper the evacuation efforts.

4.1.4 Evacuation.

4.1.4.1 Required Flotation Equipment.

As defined in FAR's 1.1 and 125.209 (appendix A), airplanes operating within 50 nautical miles of the nearest shoreline, as in this case, are not required to be equipped for extended overwater operations. The airplane was equipped with nonfloatable type seat cushions and passenger underseat lifevests. The airplane was also equipped with slide/rafts at the eight floor level exits.

4.1.4.2 Flotation Equipment Performance.

a. Although the seat cushions were of the nonfloatable type, some of the passengers believed they would serve as a flotation aid. When the cushions were thrown into the water, they immediately filled with water and sank.

b. Several passengers reported difficulties in removing the lifevests from their stowed positions and opening the plastic packaging. One flight attendant stated she had to use her teeth to remove the vest. The presence of near to sub freezing air and water temperatures may have magnified the difficulties in the removal of the lifevests.

c. Of the eight slide/rafts installed on the airplane, the six rearmost deployed successfully. The remaining two were separated from the fuselage with the nose section. However, only the R-3 overwing slide/raft was completely effective in evacuating the passengers. The reverse thrust of the No. 2 centerline engine completely disabled the L-4 slide/raft, and partially disabled the R-4 and L-2 slide/rafts.

4.1.4.3 Crew Response.

Several factors impeded the efforts of the crew during the evacuation, including the near freezing atmospheric temperature, freezing water temperature, darkness, light precipitation, fuselage separation at the nose section, and exhaust and noise created by the engine thrust reverser.

The crew were able to overcome these difficulties to successfully evacuate the passengers. The two fatalities were a result of the extreme localized vertical loading, and could not have been prevented by any postimpact crew actions.

4.1.5 Airport Proximity & Rescue Operations.

The accident occurred during a landing on icy runway conditions and led to a runway overrun. The Boston airport is almost entirely surrounded by water, with the largest body being to the southeast. The runway used during this accident, 15R, runs in this direction (figure B-2). Boston Harbor can be described as a " significant body of water." The passengers were therefore at risk of inadvertent water impact even though the flight did not involve extended overwater operations.

Initial airport rescue operations proved to be timely and successful. Logan Fire Department personnel were immediately notified and crash-rescue emergency vehicles and personnel were at the scene within four minutes to provide illumination and to assist the passengers out of the water. In addition, fire personnel used extinguishing agents in an unsuccessful attempt to shut down the No. 2 centerline engine. Upon reaching the shoreline, the passengers were exposed to prolonged periods of harsh weather without sufficient provisions as they waited to be taken to a suitable shelter.

Several other public service agencies responded to the accident, including the Metropolitan District Police, Boston City Fire Department, Boston City Police Department, Boston Department of Health, local hospitals, and the United States Coast Guard. The Coast Guard immediately dispatched three cutters, four utility boats, one Coast Guard Helicopter, and two Navy helicopters, but none arrived at the scene in time to assist in the evacuation efforts.

4.1.6 NTSB Findings.

Although the recommendations issued to the FAA primarily involved preimpact conditions, the Safety Board expressed the following concerns regarding impact and postimpact aircraft and crew responses:

a. The Logan disaster plan placed insufficient attention to the transportation and comfort of the survivors of an accident, particularly to meet the needs of 200 or more people.

b. The emergency plans, facilities, and equipment at airports should include the capability for water rescue for all conditions which might be encountered, including extreme winter weather when ice floes inhibit small rescue boat operations.

c. Some passengers reported that they had encountered difficulties in removing the lifevests from their stowed position and in opening the plastic packaging.

d. Some passengers believed that their seat cushions would serve as flotation aids, when in fact the seat cushions were not of the flotation type.

4.1.7 Analysis.

This accident involved a runway overrun following a landing 2,800 feet beyond the touchdown threshold of the 9,191-foot snow and ice covered runway. The ground speed of the airplane as it crossed the end of the runway was approximately 46 knots. The airplane was substantially damaged after coming to rest in the shallow waters of Boston Harbor. The fuselage sustained damage just aft of the nose section. Localized vertical loading resulted in the almost complete separation of the nose section from the fuselage and subsequent failure of the surrounding seats. Two occupants seated in the first passenger row were thrown from the wreckage along with their seats and are presumed dead. Otherwise, the occupiable volume was not violated and there were no cabin obstructions during the evacuation.

The survivors were presented with two main difficulties during the evacuation process. The first involved the center engine thrust reverser. This engine could not be shut down. The reverse exhaust from the engine inhibited the use of three of the eight slide/rafts, and the noise generated caused confusion among the crewmembers and passengers. The second problem involved the performance of the personal flotation devices. Many passengers assumed that the seat cushions were of the floatable type and threw them into the water. The seat cushions were not the floatable type and immediately absorbed water and sank. The passengers also experienced difficulties in removing the lifevests from the plastic packaging. Because of this and similar reports of difficulties in removing lifevests, a Technical Standard Order (TSO) C13d was issued.

The unavailability of some of the slide/rafts during the evacuation did not affect passenger survivability. Had the accident occurred in deeper water, the survival of those passengers who were unable to board the rafts would have depended on immediate rescue from the frigid 30°F waters. Advisory Circular 150/5210-13, dated May 4, 1972, suggests planning procedures, facilities, and equipment necessary to perform rescue operations when an aircraft lands in water and no normal rescue services are available.

## 4.2 AIRCRAFT ACCIDENT REPORT - SCANDINAVIAN AIRLINE SYSTEM, FLIGHT 901, MCDONNELL DOUGLAS DC-10-30, NORWEGIAN REGISTRY LN-RKB, JOHN F. KENNEDY INTERNATIONAL AIRPORT, JAMAICA, NEW YORK, FEBRUARY 28, 1984.

4.2.1 Accident Brief.

On February 28, 1984, Scandinavian Airlines System flight 901, a regularly scheduled international passenger flight from Stockholm, Sweden, to New York City, New York, was on final approach to John F. Kennedy International Airport. The DC-10-30 touched down 4,700 feet beyond the threshold of the 8,400-foot runway and overran the runway into Thurston Bay. The accident occurred in daylight hours and resulted in one serious and 11 minor injuries among the 14 crewmembers and 163 passengers.

4.2.2 Structural Damage.

The nose of the airplane came to rest in the tidal waterway approximately 160 feet from the end of the runway overrun area (figure 2). The leading edge of the left wing was embedded in a wooden pier structure which supported the approach lighting system. The aft section of the airplane remained generally intact, however there was major damage to the lower nose area, to the radome, and to the forward pressure bulkhead at fuselage station (FS) 275. The damage was caused by hydrodynamic pressure generated during impact with the water.

The interior of the forward fuselage area was deformed. The wings, leading edge, and flaps sustained moderate damage from impact with the wooden pier. Several floor beams beneath the galley were fractured. The nose gear collapsed and its drag braces fractured and separated from their attachment fittings. Wing engines Nos. 1 and 3 sustained impact and salt water damage. The No. 1 engine pylon structure was also buckled and twisted. The No. 2 engine sustained no impact damage.

This accident was survivable. With the exception of the minor seat damage in the galley area aft of the cockpit, the seats and restraint systems remained intact. The decelerative forces experienced by the passengers did not exceed known human tolerance limits and the occupiable space on the aircraft was not violated.

4.2.3 Subsystem Participation.

The only cabin deformations were on the floor and ceiling areas around exit door R-1 between the forward three galleys and the two lavatories. The floor in these areas was disrupted and displaced upward, exposing twisted and fractured floor beams. The ceiling in these areas was disrupted by displaced galley units.

The left galley unit was tilted aft and inboard two inches at the top. At the bottom, the galley unit was displaced forward and upward two inches, contacting the observer's jumpseat. The jumpseat was found loosely attached to the cockpit floor. The aft bolts were loose and still in place but the nuts were not found. After laboratory analysis, it was confirmed that the threads on the bolts had been stripped. The center galley unit was displaced upward and was tilted aft. Some of the galley doors and locks sustained damage but did not separate. Although the galley units were tilted, displaced, and damaged, all of the galley equipment remained stowed.

The cabin section aft of row 1 was generally undamaged. All overhead bins and panels were intact. There was no sidewall or floor disruption in this section.

The airplane was equipped with eight exits (figure C-2). These exits consist of the L-1 main boarding door, the L-2 aft entry door, the R-1 forward galley door, the R-2 aft galley door, and four overwing exits, L-3, L-4, R-3, and R-4. The L-1 door was opened and the slide/raft was deployed and inflated. The R-1 door was found closed with extensive damage to the forward panel covering the door handles.

FIGURE 2. JOHN F. KENNEDY AIRPORT RUNWAY GRADUAL SLOPE TO WATER

The L-2 door was opened and the slide/raft was inflated, detached, and was found floating near the approach light pier. The R-2 door was opened and the slide/raft was inflated and it was also found floating in the basin near the shore. The L-3 door was found closed and was not used during the evacuation procedure. The R-3 door was opened and the slide/raft was properly deployed and inflated.

The left aft door, L-4, had been opened with the slide/raft deployed but the flight attendant chose not to inflate it. The R-4 door was opened with the slide/raft deployed but it did not inflate due to a fabric tear in the lower right side chamber. The slide/raft did not inflate due to a fabric tear of the lower right side chamber.

4.2.4 Evacuation.

4.2.4.1 Required Flotation Equipment.

The airplane was properly certified, equipped, and maintained in accordance with existing regulations and approved procedures in the State of Registry (reference 5). This flight was characterized as an extended overwater flight. The airplane was equipped with the necessary slide/rafts at all exit doors as well as flotation equipment for all passengers.

4.2.4.2 Flotation Equipment Performance.

a. Passenger Seat Cushions/Lifevests: There were no reports of seat cushions or lifevests used as flotation devices. The passengers and crew knew that they had touched down on the runway but failed to realize that they had come to rest partially in the water.

b. Slide/Rafts: Of the eight cabin exit doors, six were opened. All six slide/raft combinations deployed automatically, and all but one inflated automatically when fired. One was not inflated because a flight attendant saw smoke arising from the engine nearby. Two slide/rafts were detached and used as rafts without being converted from a slide to a raft configuration. There were approximately twenty passengers in each of these rafts. One slide/raft, which automatically inflated, hung up and did not inflate properly when the door was opened. The flight attendant saw that it was folded in half and proceeded to kick it open. The slide/raft deflated shortly after it was kicked open.

One slide/raft deployed automatically but failed to inflate even though the inflation cylinder was discharged. The slide/raft was stretched out on the ground, and subsequent investigation found components of the slide/raft had separated. A fabric tear, 12 inches laterally and 26 inches longitudinally, was discovered 36 inches from the top of the slide on the bottom of the lower right side chamber. Twigs and debris were found in both aspirator inlets. After laboratory examination, two small punctures in the outboard left upper chamber and a small hole, 3/4 inch in diameter, near the top upper chamber were also found.

4.2.4.3 Crew Response.

When the airplane came to rest, one crewmember prematurely initiated an evacuation. The flight attendants in the rear of the airplane waited until they saw the actions of the forward flight attendants before they initiated an evacuation. The emergency evacuation was calm and controlled. All passengers were evacuated in 60 to 90 seconds.

4.2.5 Airport Proximity.

The accident occurred during the landing phase of the flight due to a runway overrun. The airport is surrounded by water on the south, southwest, and southeast, which encompasses five of the eight airport approach corridors. Thurston Basin, a tidal waterway, can be described as a " significant body of water."

Airport rescue operations proved to be timely and successful. The Port Authority of New York and New Jersey, which owns and operates the airport, were the first to send personnel to the crash site. The Crash/Fire/Rescue (CFR) units responded with six trucks and 12 firefighters. The first two trucks arrived on the scene in slightly over one minute. By then, approximately 80 percent of the passengers had exited the airplane.

The CFR crew chief entered the water and pulled the rafts with passengers and crewmembers to safety. He also helped two passengers in the water. Firefighters escorted passengers standing on the left wing onto the approach light pier and then to safety. The crew chief stated that all passengers and crew were clear of the airplane 5 to 7 minutes after the initial call.

4.2.6 NTSB Findings.

a. Apply the findings of behavioral research programs and accident/incident investigations regarding degradation of pilot performance as a result of automation to modify pilot training programs and flight procedures so as to take full advantage of the safety benefits of automation technology.

b. Direct air carrier principal operations inspectors to review the airspeed callout procedures of assigned air carriers and, where necessary, to require that these procedures specify the actual speed deviations from computed reference speeds.

4.2.7 Analysis.

This accident involved a runway overrun following a landing 4,700 feet beyond the touchdown threshold of the 8,400-foot runway. The ground speed of the airplane as it crossed the end of the runway was approximately 36 knots. The airplane was substantially damaged after coming to rest in the shallow waters of Thurston Basin. Although this accident did not involve high decelerative forces, it resulted in a minor fuselage crack aft of the nose section. The occupants were not exposed to any life threatening hazards. Immediately after the aircraft came to rest, a successful evacuation was performed in 60 to 90 seconds. Two slide/rafts were used in this evacuation, with approximately 20 passengers occupying each raft. The remaining passengers remained on the left wing until rescue personnel assisted them to safety. Had this accident occurred in deeper water, the problems experienced by the flotation equipment may have affected the passengers' survivability. The effectiveness of the personal flotation equipment was not tested during the evacuation.

## 4.3 AIRCRAFT ACCIDENT REPORT - USAIR, INC., BOEING 737-400, LAGUARDIA AIRPORT, FLUSHING, NEW YORK, SEPTEMBER 20, 1989.

### 4.3.1 Accident Brief.

On September 20, 1989, USAir, Inc. Flight 5050, a Boeing 737-400, was departing under instrument flight conditions from LaGuardia Airport in New York City for Charlotte Douglas International Airport in Charlotte, North Carolina. The takeoff was aborted and the aircraft ran off the wet runway into Bowery Bay. The accident occurred in darkness and resulted in minor injuries to both pilots and all four crewmembers. Two of the 57 passengers were killed, 15 were injured.

### 4.3.2 Structural Damage.

After leaving the runway, the airplane impacted the pier which supports the approach lighting system. Timber from the pier structure penetrated and the fuselage in two locations, causing the fuselage to separate into three sections (figure 3). Although the overall impact forces were minor because of the low velocity when the airplane left the runway, seat rows 4 and 21 sustained severe vertical impact loads. Although the left and right wings and engines remained intact, there were reports of fuel contamination in the water surrounding the crash site.

This accident was survivable. With the exception of the areas surrounding passenger seat rows 4 and 21, the decelerative forces experienced by the passengers did not exceed known human tolerance limits, the seats and restraint systems remained intact, and the occupiable space on the aircraft was not violated.

### 4.3.3 Subsystem Participation.

Decelerative forces were not great enough to cause any seat dislocations or seat belt/shoulder harness separations. The only seat damage was caused by fuselage crush and subsequent floor displacement.

Floor displacement was the primary cause of two fatalities. Timber from the wooden approach light pier structure penetrated the fuselage and forced the floor section and surrounding seats upwards, crushing four passengers against the ceiling. Two passengers in row 21 were killed by asphyxia caused by compression of the chest and two passengers in row 22 sustained serious multiple injuries. A piece of wood also penetrated the forward cockpit bulkhead, but did not produce any seat dislocations and caused only minor injury to the captain. The airplane was equipped with eight exits (figure C-3): the L-1 main boarding door, the L-2 aft entry door, the R-1 forward galley door, the R-2 aft galley door, and four overwing exits. All exit doors, with the exception of the L-1 and L-2, were used during evacuation. The L-1 door could not be opened by the lead flight attendant, and the L-2 door was closed when water began entering the cabin. The R-1 slide was successfully deployed. The flight attendant disarmed the R-2 slide before the door was opened to prevent the slide from blocking the exit area. Both the left and right overwing exits operated successfully during evacuation.

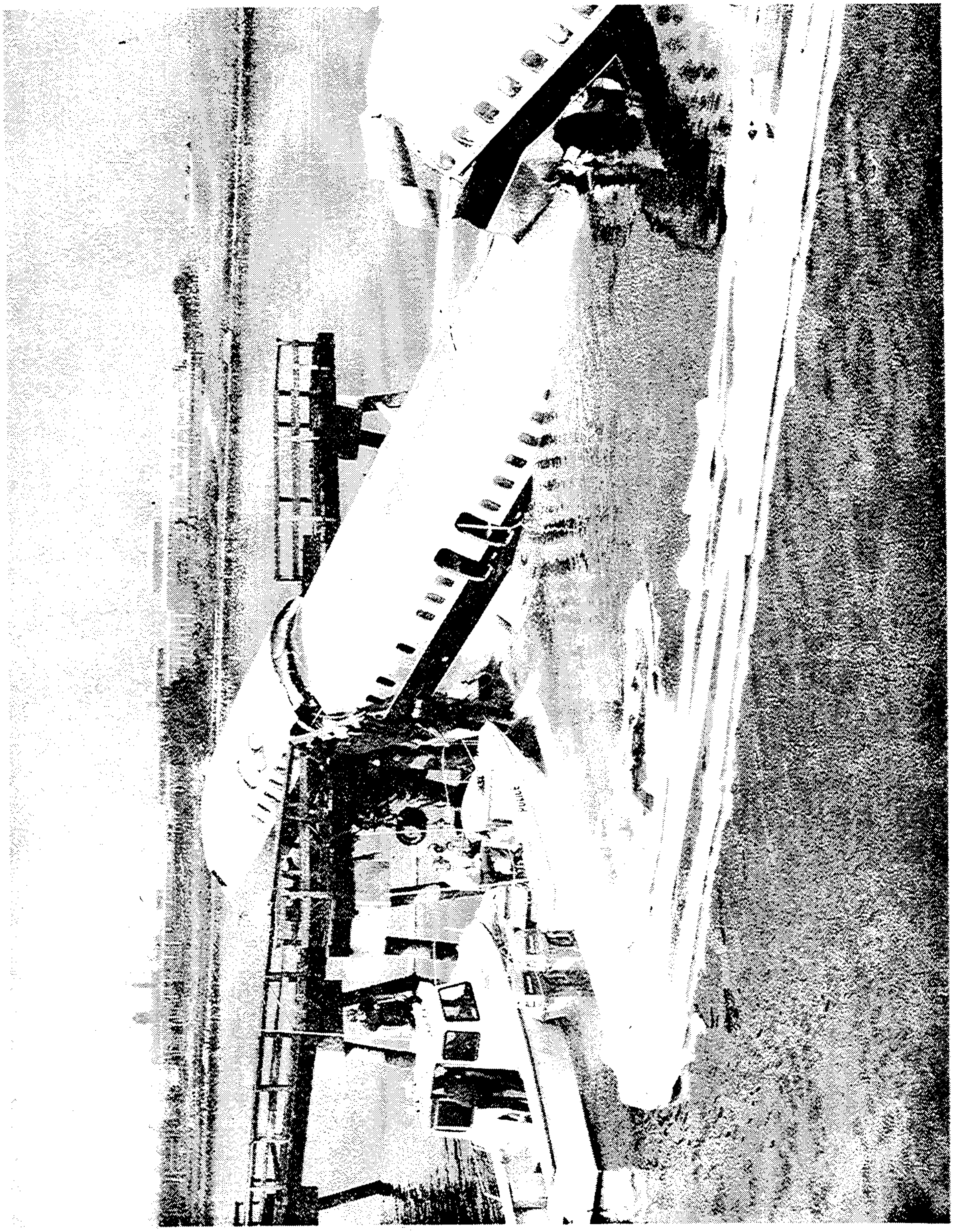

FIGURE 3 US AIR B737-400 AFTER COMING TO REST ON LIGHTING STANCHION IN BOWERY BAY

4.3.4 Evacuation.

4.3.4.1 Required Flotation Equipment.

Airplanes operating within 50 nautical miles of the nearest shoreline, as in this case, are not required to be equipped for extended overwater operations. The airplane was equipped with flotation seat cushions for the passengers. Although lifevests were carried by the crewmembers, they were not required for passengers. The airplane was equipped with the required slides at the four nonwing exits, as well as ditching lines on the right and left overwing exits.

4.3.4.2 Flotation Equipment Performance.

a. Passenger Seat Cushions: Crewmembers assisted those passengers who used the floor level exits by throwing the flotation seat cushions into the water. Several passengers complained that they could not hold onto the seat cushions and that they were ineffective in keeping them afloat. The performance of the seat cushions was hampered by the 1-knot water current as well as the waves created by rescue boats and the downwash of a rescue helicopter, all of which made it difficult for the passengers to keep their heads above the water.

b. Crew Lifevests: During evacuation, the crewmembers threw their lifevests into the water to aid passenger flotation. Although there were no reported problems in the use of the lifevests, there were only a small number available.

c. Slides: Of the four exit doors which were equipped with automatic slides, two were opened and used for evacuation. The aft exit door slide was disarmed due to its proximity to the water level, leaving only one slide available for evacuation. This slide was successfully deployed and was used in the evacuation of passengers from the forward floor level exit.

d. Ditching Lines: Many passengers used the left and right overwing emergency exits. Some of the passengers on the left wing unstowed the fabric ditching lines and were able to successfully fasten the line to the wing tip fitting and await rescue. Although the passengers on the right wing were unaware that the ditching line needed to be tied down to the wing tip fitting, they still held onto the line to stay out of the water.

4.3.4.3 Crew Response.

Several factors impeded the efforts of the crew during the evacuation; including, darkness, fuselage separations at seat rows 4 and 21, and two unavailable floor level exits. In addition, the cabin megaphone which the captain attempted to use had an unorthodox volume adjustment knob which turned to the left to increase the volume. This led to "squelching" or feedback problems, making it easier for the captain to simply yell out the evacuation commands. The megaphone got wet and later malfunctioned completely.

In general, the crew overcame these difficulties to successfully evacuate the passengers from the airplane. The two fatalities could only have been prevented if the passengers were immediately extracted from the wreckage and put on life support.

Although the flight attendants were not trained in "wet" drills, they reacted immediately upon realizing that an overrun was inevitable. They prepared the passengers for impact by instructing them to brace as the airplane crossed the end of the runway. As the airplane came to rest, the flight attendants assessed the outside conditions at their assigned exit doors and initiated an evacuation. The attendant at exit R-2 realized that deploying the slide would block the exit door due to the high water level surrounding the exit. Her decision to disarm the slide before opening the door expedited the evacuation process as the exit would have otherwise become unusable. Upon opening the exit door at L-2, water began entering the cabin. The attendant assigned to this exit immediately closed the door to prevent additional water from entering the cabin. Two flight attendants entered the water and linked arms to support two passengers who were unable to swim.

#### 4.3.5 Airport Proximity.

The accident occurred during an aborted takeoff and led to a runway overrun. The airport is surrounded by water on the northwest, northeast, and southeast, which encompasses three of the four airport approach pathways (figure B-4). Bowery Bay can be described as a "significant body of water." The passengers were therefore at risk of inadvertent water impact even though the flight did not involve extended overwater operations.

Airport rescue operations proved to be timely and successful. The Port Authority was the first to send personnel to the crash site. Within 90 seconds of the crash, three aircraft rescue and fire fighting (ARFF) trucks were positioned at the end of the runway deck, followed shortly thereafter by two additional ARFF trucks. Disorientation and a lack of escort vehicles delayed the arrival of both New York City Police Department (NYPD) vehicles and New York City Fire Department (NYFD) vehicles. A Port Authority police officer jumped into the water with a large inflatable life ring to assist the passengers in the water. The Port Authority's 19-foot rescue boat was unable to be launched as the truck which towed the boat could not develop enough traction on the dike.

The first boat on the scene, sent by the NYPD's Harbor Unit, arrived approximately 10 minutes after the accident occurred. Shortly thereafter, U.S. Coast Guard boats, boats from other agencies, and one of the two dispatched Coast Guard helicopters arrived at the accident scene. Although darkness hampered the efforts of the search and rescue personnel, the most significant problem involved the passenger count. Rescue personnel did not have an accurate count of the number aboard the aircraft, the number of persons in the water, or the number of persons already evacuated and taken from the scene.

#### 4.3.6 NTSB Findings.

a. Develop standards for the design, construction, operation, and performance of cabin megaphones.

b. Require airlines to provide airport crash/fire/rescue personnel with accurate and timely numbers of all persons aboard an accident/incident aircraft. Provide assistance in determining the disposition of persons who have been recovered from the scene of an accident.

c. Require air carriers to adopt procedures that would result in the completion of a modified or full acceptance checklist whenever the flight crew has vacated the cockpit.

d. Direct all principle operations inspectors to urge air carriers to issue an Air Carrier Operations Bulletin to schedule newly trained captains and first officers on regular trip schedules immediately following completion of training until they accrue a prescribed amount of line operating time in order to consolidate their recently acquired training.

e. Amend FAR Part 121.385 to specify a combined experience level for initial pilot-in-command and initial second-in-command pilots which would preclude the pairing of two inexperienced pilots.

NTSB made the following recommendations to the Port Authority of New York and New Jersey. Survey the 1,000 by 500 foot surface area contiguous to the departure ends of the runways at the LaGuardia Airport in order to minimize hazards to airplanes that do not stop on the runways.

The NTSB reiterated the following recommendation to the FAA. Amend FAR Parts 121,125, and 135 to require that the cockpit and cabin crewmembers be given periodic training, including hands-on "wet" drills, in the skills relevant to inadvertent water impact that may increase the chances of postcrash survival.

4.3.7 Analysis.

This accident involved an aborted takeoff during wet runway conditions which resulted in a runway overrun. The ground speed of the aircraft as it crossed the end of the runway was approximately 46 knots. The airplane was completely destroyed after coming to rest in the shallow waters of Bowery Bay. The runway overrun involved higher than normal vertical loading upon impacting the approach lighting pier which resulted in fuselage separations. This exposed the occupants to hazards including displacement of the cabin floor, separation of passenger seats, and contact with cabin debris. Two fatalities resulted. The occupiable volume was violated with such severity that the fatalities could have been prevented only upon use of immediate life support equipment. Although the lifevests proved to be effective in survival assistance, very few vests were available. Several passengers complained that the flotation seat cushions were ineffective in keeping their heads above water and they were difficult to hold onto.

## 4.4 CASE STUDY DISCUSSION.

### 4.4.1 Injury/Fatality Summary.

Injury Data

| Injuries | Crew | Passengers | Other | Total |
|---|---|---|---|---|
| Fatal | 0 | 4 [1] | 0 | 4 |
| Serious | 2 | 6 | 0 | 8 |
| Minor | 14 | 39 | 2 | 55 |
| None | 16 | 365 | 0 | 381 |
| Unknown | 0 | 3 [2] | 0 | 3 |

[1] Including 2 lost passengers presumed to be dead
[2] Hospital records unavailable

Fatality Data

| Case | Trauma | Drowning |
|---|---|---|
| CASE 1 | 2 [1] | 0 |
| CASE 2 | 0 | 0 |
| CASE 3 | 2 | 0 |
| TOTAL | 4 | 0 |

[1] The impact forces are assumed to have been sufficient enough to be the primary cause of the presumed fatalities, although it is possible that drowning occurred.

### 4.4.2 Structural Damage.

All three accidents involved runway overruns into water. One resulted from an aborted takeoff and two from long landings. The overrun cases involved damage to the fuselage just aft of the nose section, from a minor crack to almost complete separation. This led to local vertical impact loads, which proved to be fatal in two cases. The velocity with which the airplane enters the water is an important factor in predicting the amount of damage sustained. The three overruns in this study were of relatively low energy and had approximately the same ground speed upon entering the water (36 - 46 knots).

The drop into the water and the presence of obstructions immediately beyond the runway increase the potential for excessive impact forces on the airplane. The LaGuardia accident included both of these hazards. Upon crossing the end of the runway, the airplane encountered a drop of approximately 10 feet into the water and a concrete/wooden pier structure positioned within 50 feet of and in line with the end of the runway. The fuselage separated in two locations. In contrast, the JFK accident involved a very gradual slope into the water resulting in no fuselage separations. Although there was an approach lighting pier located directly beyond the runway, the landing gear remained on the ground and the pilot was able to swerve the airplane to avoid it.

In the case of runway overruns, the majority of fatalities result from high-energy impact with obstructions and subsequent fuselage breaks. Although obstructions such as approach lighting piers may be necessary, they pose a threat to the safety of the aircraft and its occupants as they are located directly in line with the path of the aircraft and are made of nondeformable materials such as concrete and wood. Based on the results of these case studies, required construction which may be obstructions should be of a frangible or energy absorbing type. As a result of the Piedmont accident at Charlotte Douglas International Airport in 1987, where a Boeing 737 overran the runway and struck a concrete culvert, the NTSB issued a recommendation calling for the removal of obstacles which are adjacent to airport operations. Although FAR Part 139.309 (b)(4) states that no objects, except those which are required because of their function, may be located in any safety area, the obstructions involved in the LaGuardia, JFK, and Boston overruns were outside of the runway safety area, and therefore not applicable to this regulation. This issue was addressed in 1987 in an amendment to FAR Part 139 in which the FAA expressed its willingness to encourage airport operators to remove all objects outside the designated runway safety area but within the dimensions of the extended runway safety area defined by the FAA's current design standards.

Allowing the airplane to gradually slide into water, as in the JFK accident, should result in minimal aircraft damage and a successful emergency evacuation of all occupants using the available flotation devices. Runway overrun areas leading into water which avoid sudden drop-offs and allow for a smooth transition into the water can reduce impact forces and prevent fuselage separations. Evidence to support this is provided by both the FAA and airport engineers. As stated in FAR Part 139.307 (a)(1), "No slope from the edge of the full-strength surfaces downward to the existing terrain shall be steeper than 2:1," thus preventing vertical drop-offs. Boston-Logan Airport Engineers have looked into the feasibility of developing sloped runway safety areas that decelerate the aircraft through the use of gravel. The model of such a sloped overrun area, developed by Boston-Logan Airport Engineers, is shown below in figure 4.

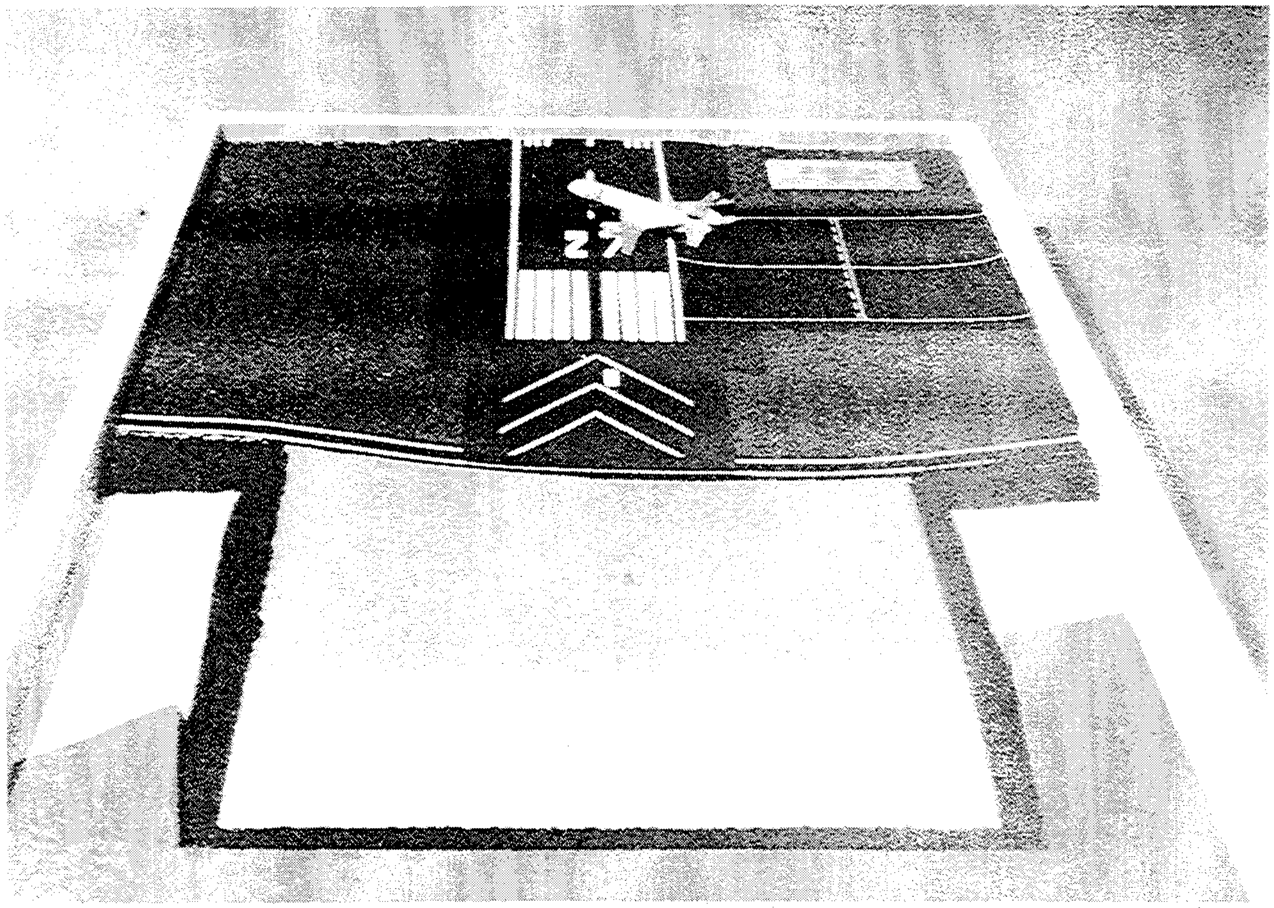

FIGURE 4. INCLINED SAFETY AREA (ISA) MODEL DEVELOPED BY BOSTON-LOGAN AIRPORT ENGINEERS

4.4.3 Subsystems.

A summary of each aircraft's structural damage is shown in table 5. The performance of each of these subsystems in the mishap are described in detail in the following section.

a. Seat Dislocation: The two instances of seat dislocations in this study were caused by localized floor displacements resulting from excessive vertical loads in which the fuselage was almost completely separated. In the case of the LaGuardia accident, the direct impact to seat rows 4 and 21 would have resulted in occupant fatalities at these locations regardless of seat dislocation. The fatalities in the Boston-Logan accident, however, may have been prevented had the seats remained attached to the seat track.

TABLE 5. STRUCTURAL DAMAGE SUMMARY 1980-1991

| STRUCTURE | CASE NUMBER | | |
|---|---|---|---|
| | 1 | 2 | 3 |
| Hull Loss | | | X |
| Fire | | | |
| Fuselage Separation | X | | X |
| Engine Separation | | | |
| Cabin Damage | X | | X |
| Seat Dislocation | X | | X |
| Gear Separation | | X | |
| Exit Door Damage/Difficulty | X | X | X |
| Floor Displacement | X | X | X |
| Cabin Debris | | | |

b. Floor Displacement: All three cases in this study resulted in floor displacements. It is interesting to look at the relationship between the amount of drop-off into the water and the degree of damage to the aircraft. The two cases involving substantial drop-offs from the runway overrun area into the water resulted in floor displacements of such significance as to cause seat dislocations and fatalities. The case which involved a gradually sloped overrun area resulted in floor and ceiling displacements but no seat dislocations or fatalities.

c. Cabin Debris: There was very little cabin debris generated in these three accidents. In the case of the JFK overrun, the galley units and overhead bins were twisted and displaced in the area just aft of the nose section, but all bins and units remained intact and did not interfere with the evacuation.

d. Occupiable Volume: Violation of the airplane's occupiable volume occurred in two of the three cases, resulting in fatalities. The intrusion into the occupiable volume resulted from excessive vertical loads which separated the fuselage and displaced the cabin floor. This led to the failure of the surrounding seats and restraint systems.

e. Exit Doors: In general, the performance of the exit doors was acceptable, although all three cases involved some degree of exit door operational difficulties. These difficulties resulted from a number of factors including fuselage separation, engine reverse thruster exhaust, damaged door control panels, and water levels which rose above the exit door openings. Out of 24 exit doors on the three aircraft, fuselage separation led to three inaccessible doors, engine reverse thruster exhaust led to one inaccessible door and two cases of exit door difficulties; control panel damage led to one inaccessible door, and high water level resulted in one inaccessible door.

4.4.4 Evacuation.

4.4.4.1 Required Flotation Equipment.

All airplanes were equipped with the required emergency flotation equipment. Two of the three cases did not involve extended overwater operations and were not required to be equipped for such a flight. In addition to the normally required flotation equipment, such as flotation seat cushions, an extended overwater flight must also carry lifevests, liferafts, and/or other flotation devices.

4.4.4.2 Flotation Equipment Performance.

a. Lifevests/Preservers: There were several reported difficulties in the use of the lifevests. In two of the accidents, passengers and crew experienced difficulties in removing the vests from their stowed positions as well as in removing the vest from the plastic packaging. Two flight attendants were forced to tear the packaging open with their teeth. This problem has been documented in several accidents involving the use of lifevests and has been addressed by the FAA through TSO-C13f, dated September 1, 1989. This states that "The means of opening the package must be simple and obvious, and must be accomplished in one operation without the use of any tool or excessive physical force."

Survivors also experienced breathing difficulties and difficulty in keeping their heads above the water. The flotation attitude, as defined in TSO-C13f, requires both "lateral and rear support of the wearer's head so that the mouth and nose of a completely relaxed wearer are held clear of the water line with the trunk of the body inclined backward from the vertical position at an angle of 30 degrees minimum." The lifevest must also right the wearer within 5 seconds should the wearer be in the water in a face-down attitude. Providing buoyancy to the shoulder area keeps the head in close proximity to the water level, thus making it difficult for survivors in strong currents or choppy water to keep their heads above water. Providing additional buoyancy to the middle torso area may serve to raise the wearer's head further out of the water while still adhering to the requirements stated in TSO-C13f. Also, it will keep a greater portion of the wearer's body out of the water, reducing the effects of hypothermia.

There are two types of approved life preservers, Type I and Type II, which are divided into "Adult," "Adult-Child," "Child," and "Infant-Small Child" groups. The Type I life preservers are of the inflatable type. Type II are noninflatable life preservers. The lifevest/preservers in most of the applicable cases were Type I. There were no reported problems relating to the inflation system. For each life preserver, survivor locator lights are required to "be automatically activated upon contact with water." In two cases, at Boston-Logan and LaGuardia, passengers entered the water in hours of darkness. The lights did not come on because the water was not deep enough for the life preservers to make contact with the water. The lack of survivor locator lights in the darkness made it difficult for the rescuers to locate all of the survivors who were "wading" through the shallow waters.

b. Seat Cushions: In all three accidents passengers had difficulties in using their passenger seat cushions. Many passengers complained that the floatable type seat cushions did not keep them afloat and were difficult to hold. During the evacuation at Boston-Logan, the nonfloatable seat cushions were mistaken for the floatable type and caused confusion and delays. In the case of a deep water accident, confusion and delays such as this could prove to be fatal.

Not all airplanes are required to carry floatable seat cushions. Those that are carried on an airplane are classified as Type II Individual Flotation Devices (IFD's), as they are noninflatable. Noninflatable IFD's include such flotation equipment as seat cushions, head rests, arm rests, and pillows. The flotation seat cushions are likely the most recognizable form of individual flotation on the airplane. In these cases, the seat cushions were the first means of flotation used by the passengers. The use of life preservers as the first means of flotation is rare unless specifically directed by the cabin crew. One reason for this is that not all airplanes are required to carry life preservers, and therefore the passengers are not familiar with their use. Secondly, a lack of attention during passenger preflight briefings leads to passengers who simply reach for the closest and most readily accessible equipment during an emergency. Seat cushions are used first, primarily for this reason.

c. Slide/Rafts: The overall performance of the slide/rafts during the evacuation procedures was acceptable. As shown in table 6, there were 16 exits equipped with slide/rafts available to the survivors. Exits which were completely destroyed or separated from the cabin by fuselage breaks were excluded from consideration. Of the 16 slide/rafts installed, 15 were armed and 11 were immediately deployed and successfully inflated. One slide briefly hung up, but was later kicked by a flight attendant and used in evacuation. One slide was partially disabled by engine exhaust. Both of the two remaining slide/rafts were deployed immediately, but were completely disabled and not used during evacuation. One slide/raft inflated successfully, but was disabled by engine exhaust. The only true malfunction of a slide/raft occurred in case 3 (LaGuardia accident). It could not be inflated due to two punctures and a large tear.

TABLE 6. SLIDE/RAFT PERFORMANCE SUMMARY 1980-1991

| Case | Total Exits | Total Exits with Slides | Available Exits with Slides [1] | Performance Comments |
|---|---|---|---|---|
| 1 | 8 | 8 | 8 | 6 Deployed/Inflated<br>1 Completely disabled by engine exhaust<br>1 Partially disabled by engine exhaust |
| 2 | 8 | 8 | 6 | 4 Deployed/Inflated effectively<br>1 Hung up briefly; later deployed<br>1 Deployed but punctured; not inflated<br>2 Used as rafts without converting from slide to raft |
| 3 | 8 | 4 | 2 | 1 Deployed/Inflated effectively<br>1 Disarmed by flight attendant |

[1] Excludes exits which were completely destroyed or separated from the cabin

d. Ditching Lines: Ditching lines were used in one of the three cases. They were necessary to secure the survivors while they awaited rescue because the airplane was not equipped with passenger lifevests. Had the ditching lines not been available, additional passengers would have been forced to use the flotation seat cushions, which are not considered by the NTSB to be an effective means of personal flotation. In addition, the ditching lines aided the rescue efforts as they were able to keep the survivors in close proximity to the aircraft. Without ditching lines, the 1-knot water current would have caused additional survivors to drift from the wreckage. It should be noted that one ditching line was not secured because some survivors were unaware of the need to tie the line down. Although this did not result in difficulties, a similar incident in deeper waters and stronger currents could lead to fatalities.

Most passengers are unaware that many airplanes are equipped with ditching lines. There is very little acknowledgement, if any, in preflight safety briefings of ditching line locations and of their proper function. Ditching lines can be used as an important supplement to individual flotation devices and lifevests. These lines cannot only be used for evacuation purposes, but also as a gathering point for the passengers.

4.4.4.3 Crew Response.

During some of the accidents, particularly those with fuselage separation, communication between the flight crew and the cabin crew was difficult. In some cases, the airplane's intercabin communication system was damaged by the impact forces and impeded the ordering of an evacuation. In a fuselage separation, the lead flight attendant or the closest flight attendant to the fuselage separation was responsible for ordering the evacuation process to begin.

Once evacuation was deemed necessary, the crews responded immediately. The flight attendants made rapid decisions by directing the passengers to the safest exit routes and preventing water from entering the cabin. Once in the water, the crew assisted the survivors in donning their lifevests and for those who did not know how to swim, helped them stay afloat while awaiting rescue.

The crews overcame many difficulties (table 7), most of which were environmental and uncontrollable. Some problems, such as engine noise and crew megaphones, were equipment malfunctions and can be dealt with. The crew's attempt to shut down the centerline engine was unsuccessful due to the fuel cutoff mechanism having malfunctioned. In case 4, the lead flight attendant attempted to use the battery powered cabin megaphone to direct the evacuation, but it had an unorthodox volume adjustment knob with which the attendant was not familiar. Later, the megaphone malfunctioned completely upon getting wet. These problems could be avoided.

TABLE 7. CREW DIFFICULTIES DURING EVACUATION 1980-1991

| CONDITION | CASE NUMBER | | |
|---|---|---|---|
| | 1 | 2 | 3 |
| Darkness | YES | NO | YES |
| Rain | YES | NO | YES |
| Snow | YES | NO | NO |
| Fog | YES | YES | YES |
| Freezing Water | YES | NO | NO |
| Noise | YES | NO | NO |
| Megaphone Malfunction | NO | NO | YES |

4.4.5 Airport Proximity.

All three cases involved runways which were bordered by significant bodies of water. Two of the three overruns resulted from long landings. The third overrun resulted from an aborted takeoff. Although only one of the overruns involved "extended overwater operations," all three flights required crossing over a significant body of water during either final approach or takeoff. According to Boeing's worldwide operations summary, 69.1 percent of all accidents occur during the flight phases within close proximity to the airport, specifically takeoff, initial climb, final approach, and landing. It is important to note that these phases make up only 6 percent of the total flight time. Based on these statistics, flights having their takeoff, initial climb, and approach phases occurring over significant bodies of water should be adequately equipped to deal with water impact accidents. In addition, airport and community rescue facilities should be adequately equipped to handle any water related emergencies.

4.4.6 NTSB Findings.

The majority of the recommendations made by the NTSB for these three cases pertained to accident prevention and flight operations. The NTSB also pointed out several deficiencies in postaccident emergency procedures. The NTSB recommendations are divided into four groups: (1) Emergency Equipment Improvements, (2) Airport Rescue Operations Improvements, (3) Airport Improvements, and (4) Proposed Regulations.

a. Emergency Equipment Improvements:

1. Recommendation A79-36: Following a B-727 accident near Pensacola, Florida (NTSB-AAR-78-13), a recommendation was made to the FAA that all passenger carrying aircraft be equipped with approved flotation type seat cushions. The FAA responded by stating that it was assessing the feasibility of imposing this requirement. Such a requirement would have aided in the evacuation procedures of the Boston-Logan accident, as the passengers assumed that the seat cushions were of the flotation type.

2. Recommendation A79-39: As a result of difficulties in opening the plastic packaging enclosing the lifevests in the Pensacola accident, a recommendation was made to the FAA that addressed standards for packaging. The NTSB requested that this change be made in a revision of TSO-C13d. The FAA produced a draft TSO revision on life preservers in 1981, but it did not address the packaging issue. Passengers and flight attendants experienced similar difficulties in the LaGuardia and Boston-Logan accidents.

3. Recommendation A90-104: Following the malfunction of the cabin megaphone during the evacuation process in the LaGuardia accident, a recommendation was made to the FAA that they develop standards for the design, construction, operation, and performance of megaphones.

4. Recommendation A85-35 through 37: As part of the NTSB's Special Study entitled "Air Carrier Overwater Emergency Equipment and Procedures" (NTSB-SS-85-02), the NTSB made a recommendation to the FAA to require all passenger carrying air carrier aircraft to be equipped with approved life preservers and reiterated the need to require flotation type seat cushions on all passenger carrying aircraft. On June 27, 1988, the FAA issued NPRM No. 88-11, which requires the use of passenger lifevests and flotation type seat cushions on all aircraft operating under Parts 121 and 135. The regulation changes did not apply to aircraft operating under FAR Part 125, however, which applies to large civil aircraft. The NTSB strongly recommended the extension of the regulations to aircraft operating under this Part.

b. Airport Rescue Operations:

Recommendation A82-88: This tasked the FAA to evaluate the adequacy of water rescue plans, facilities, and equipment at certified airports having approach and departure flightpaths over water. This resulted from Boston's Logan airport accident where it was determined by the NTSB that the airport disaster planning did not place importance on the transportation and comfort of the survivors. Also, they stated that if the accident had occurred in deeper water, with the same frigid temperatures, the lack of a detailed water rescue plan would have negatively affected the survivability of the occupants. In May 1991, the FAA published Advisory Circular 150/5210-13 entitled "Water Rescue Plans, Facilities, and Equipment." The FAA's Advisory Circular suggested that airport emergency plans, facilities, and equipment include water rescue capability for **all** conditions which **might** be encountered. An example of an airport which could have benefited from this advisory circular is Washington National in 1982, following the Boeing 737 crash into the ice covered Potomac River. In this case, the rescue personnel were not prepared for these conditions as the equipment which was used during the rescue operations was never tested for performance on ice.

c. Airport Improvements:

1. Recommendation A72-3: In 1972, and again in 1982, the NTSB recommended the installation of distance markers along the outer edge of the runway. The use of markers would aid the pilots in landing as it would identify the touchdown point relative to the remaining length of runway. The markers could also be used to collect data on stopping on contaminated runways. This data can then be compared to published performance data for dry runways and used as a basis for estimating braking performances on contaminated runways.

2. Recommendation A77-16: As a result of the increased frequency of aborted takeoffs leading to runway overruns, the NTSB recommended to the FAA that they amend FAR Part 139.45. This requires all certified airports to provide an extended runway overrun area of approximately 1,000 feet. The FAA realized that this would be physically impossible for some airports and place an economic burden on others, and the revised regulations called for the above safety area dimensions only if " the construction, reconstruction, or significant expansion of runways/taxiways began on or after January 1, 1988."

The use of plastic foam as an aircraft arresting material to prevent runway overruns was first proposed by the Royal Aircraft Establishment in 1974 (reference 14). In 1986, the FAA initiated research on a phenolic foam Soft Ground Arrestor System (SGAS) as a means to safely stop aircraft which overrun the runway during takeoff abort or landing (references 15, 16, and 17). The target users of this system are those airports with geographical restrictions on the length of a runway as well as those airports with obstructions or steep drop-offs at the end of the runway. In general, the runway safety areas at these airports are less than the required 1,000 feet. The SGAS occupies a length of only 600 feet beyond the end of the runway and therefore provides an alternate means of compliance with the 1,000 ft. safety area requirement. On June 22, 1993, the FAA successfully concluded a series of field tests using its instrumented B-727 aircraft at its Technical Center at Atlantic City International Airport in New Jersey (reference 18). The final test consisted of taxiing the B-727 into a full-scale phenolic foam SGAS at approximately 60 knots.

3. Recommendation A87-107: The NTSB recommended that the FAA require airport managers to repair and/or remove obstacles that are adjacent to airport operating areas. In the LaGuardia accident, the airplane struck a wooden pier which was supported by concrete pylons. Although the wooden pier alone would not have caused excessive damage to the interior cabin, the presence of the concrete pylons led to the localized destruction of the occupiable aircraft space and subsequent fatalities. The FAA, in an amendment to FAR Part 139, expressed its willingness to instruct its Airport Certification Inspectors to encourage airport operators to comply with the above mentioned recommendation to remove the obstructions.

4. Recommendation A87-112: The NTSB recommended to the American Association of Airport Executives and the Airport Operators Council International, Inc. that its members should repair and/or remove obstacles that are adjacent to airport operating areas.

d. Proposed Regulations

1. Recommendation A90-105: This recommendation would require airlines to provide airport rescue personnel accurate and timely numbers of all persons aboard an accident/incident aircraft, and to provide assistance in determining the disposition of persons who have been recovered from the scene of an accident. Boston's Logan airport accident involved two passengers who were never recovered from the accident scene and are presumed dead. The search and rescue operations were terminated within hours of the accident because the rescue personnel were led to believe all occupants had been accounted for, but the occupant count given to the rescue personnel was short by one passenger. Several days passed before it was determined that two occupants were unaccounted for.

2. Recommendation A90-106: Would require air carriers to adopt procedures that would result in the completion of a modified or full acceptance checklist whenever the flightcrew has vacated the cockpit.

3. Recommendation A82-88: Would survey all certified airports whose approach and departure flight paths are over water and evaluate the adequacy of their water rescue plans, facilities, and equipment, and make recommendations for improvement as necessary to appropriate airport authorities.

4. Recommendation A82-89: Amend FAR Part 139.55 to require adequate water rescue capabilities at airports having approach and departure flightpaths over water which are compatible with the range of weather conditions which can be expected.

5. Recommendation A85-49: Would require cockpit and cabin crewmembers on aircraft being operated over water to be given periodic training, including hands-on "wet" drills, to increase the chances of postcrash survival.

4.4.7 NTSB Safety Studies.

a. NTSB-SS-84-02 (reference 19): This safety study, "Airport Certification and Operations," evaluated the nature and scope of regulations governing airports, the FAA's method of assuring compliance with the regulations, and the FAA's airport inspections procedures. It also analyzed air carrier accidents which occurred in the United States from 1964 to 1981 in which airplanes had traversed areas adjacent to runways.

The study reiterated the need for runway distance markers, stating that they "would provide to flight crews a way of quickly ascertaining the amount of remaining runway..." The use of distance markers was subsequently re-evaluated by the FAA, and their use is now permitted on any runway.

The study also addressed the issue of runways and their immediate surroundings. Of most concern was the issue of runway safety areas. By regulation, runway safety areas, where possible, should be at least 500 feet wide and should extend 1,000 feet beyond the end of each runway. At some airports, this is not physically possible because of geographical barriers, conflicting interests, and/or improper land use. Of particular concern are those runways surrounded by geographic barriers such as significant bodies of water. Some airports, such as LaGuardia Airport, have runways with an immediate drop-off into the water. Figure 5 shows the drop-off at the end of runway 31 at LaGuardia Airport, and the extensive damage suffered by the fuselage of the USAir Boeing 737 when it aborted a takeoff and overran the runway. A possible alternative to a runway safety area was investigated by Boston's Logan airport engineers. This unique plan consisted of constructing an inclined safety area (ISA) which gradually slopes downward at the ends of runways bordered by water. This concept provides a transitional surface, covered with loose gravel or crushed stone, from the runway to the water which would significantly improve the stopping capability of the aircraft without having to increase the runway length. Figure 2 shows a runway located at JFK International Airport, the minimal damage sustained by the fuselage of the Scandinavian Airline's DC-10 when it overran the runway, and is a practical example of a runway which employs the ISA technique.

The Safety Board also found that many airports had various types of mounted equipment located within the boundaries of the runway safety areas. This consisted mainly of approach lighting aids. Many of these were found to be constructed on nonfrangible stanchions, thus becoming a hazard to aircraft in the event of an overrun. In some cases, such as runways bordered by water, frangible structures, although desirable, are not used because of the complexity of the structure and the lack of design criteria set by the FAA or ICAO for structures of this type.

The safety study concluded that since the inception of the FAA Airport Certification Program there has been a measurable improvement in airport safety. The study acknowledged that many airports cannot comply with the extended safety area regulations because they are limited by either economic or geographical barriers. For runways bordering water, the soft-ground arresting concept, i.e., ISA, may be both economically and physically feasible (A-84-37). Research should also continue in the area of developing frangible, low-impact resistance designs for submerged structures located within runway extended safety areas (A-84-36).

b. NTSB-SS-85-02 (reference 13): This safety study "Air Carrier Overwater Emergency Equipment and Procedures" discussed various improvements in FAA emergency equipment and procedural regulations regarding overwater operations. The study states that the fundamental problem with "...current water survival-related regulations is that they focus primarily on ditchings occurring at sea on extended overwater flights." But in their accident analysis, the NTSB found that virtually all survivable water accidents are inadvertent, and furthermore, most "have occurred near an airport, during approach or departure." An FAA staff study, referenced by the NTSB, "found that at least 179 fully certified airports in the U.S. are located within 5 miles of a body of water of at least one-quarter square mile surface area."

Because of the number of airports near significant bodies of water, the NTSB suggested that all air carrier aircraft should carry certain basic flotation equipment such as approved flotation seat cushions and life preservers for each occupant. Flotation seat cushions are recommended for one important reason. In an inadvertent impact with fuselage separation, the seat cushions would most likely float to the surface and thereby aid the survivors. Life preservers are also recommended in addition to individual flotation devices (IFD's) for two basic reasons. First, and perhaps most

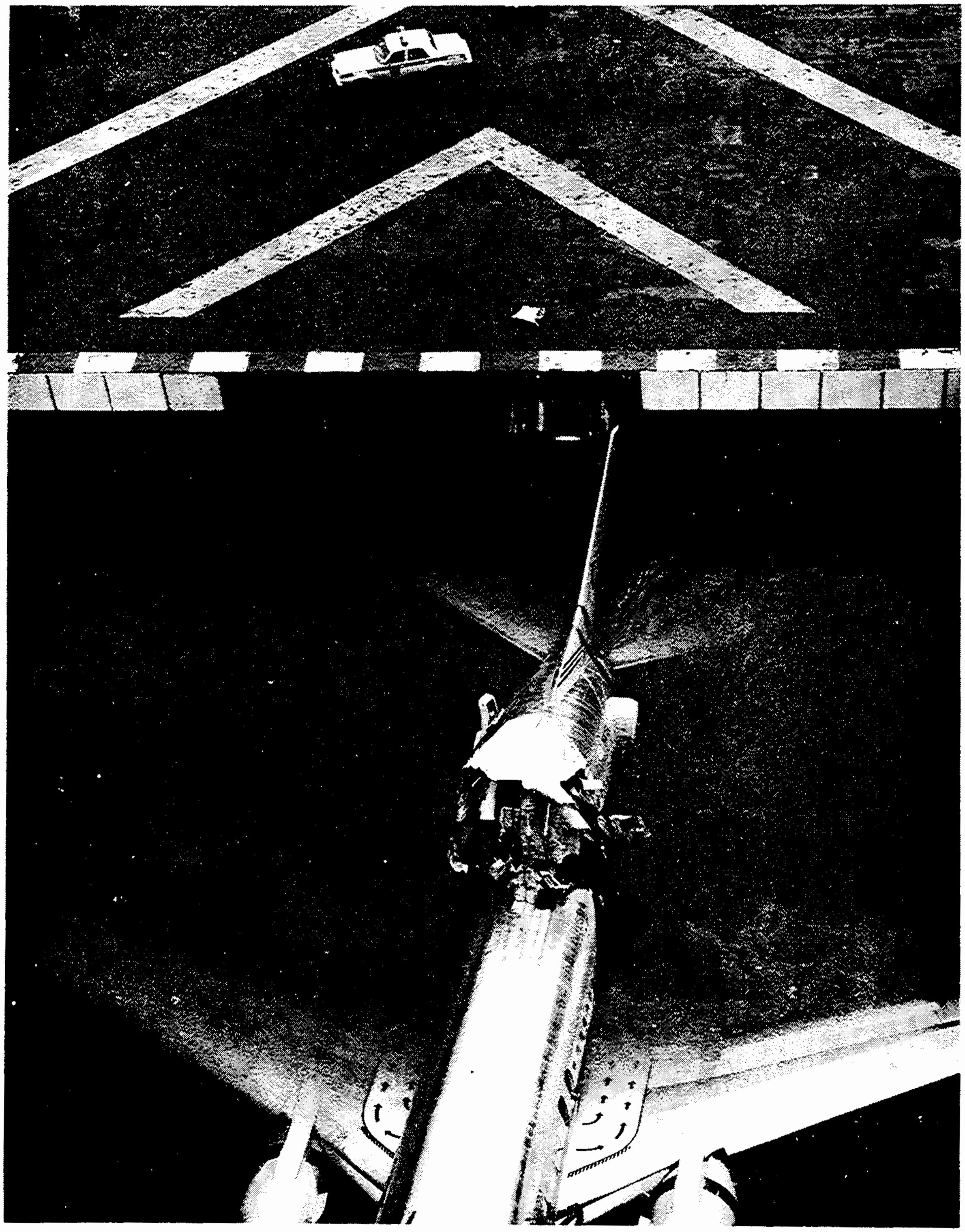

FIGURE 5. LAGUARDIA AIRPORT RUNWAY DROP-OFF TO WATER

important, they have greater buoyancy than IFD's. Also, they are regulated by being subjected to a series of donning tests as required by TSO-C13.

Several problems were found by the NTSB in its examination of current life preserver designs. Most notably, these problems existed. "...in the areas of stowage, packaging, sizing, donning, ability to maintain user's upright position, and tendency to channel water into the user's face." Although life preservers must be easily accessible and its compartment must be conspicuously marked and protected, results of accident analysis have shown that, even when sufficient preparation time exists, occupants still have difficulties in unstowing them. The plastic packaging hampers the effectiveness of the life preserver because of the extraordinary amount of force required to open them. In several accident cases, the occupants had to use their teeth or some sort of sharp object to rip the packaging open. Once the package is opened, the occupant faces another challenge in properly donning it. In many of the previous cases studied by the NTSB, problems in donning life preservers ranged from taking the seat belt off to put on the vest to actually getting tangled in the vest's adjustable straps. The NTSB felt that the regulations regarding the certification of the life preservers for use on transport airplanes were too vague and that manufacturers used this to their advantage.

Another problem uncovered by the NTSB involved the sizing of life preservers. The existing designs with adjustable straps were too complex for occupants to use properly. The safety of infant-sized life preservers were of particular concern because of the greater risk of hypothermia to infants. The objective of life preservers made specifically for infants and children is to not only provide a means of buoyancy, but also to provide some form of protection against hypothermia. The study also stated that automatically activated survivor locator lights should be installed of all life preservers. Although the Safety Board has continued to investigate various concepts of child- and infant-sized life preservers, it believes that further research is necessary.

Extended overwater flights are required not only to carry individual flotation devices but also to carry life rafts. Most wide-body aircraft meet this requirement with slide/raft combinations. Narrow-body aircraft, however, are not equipped with slide/raft combinations therefore, they are required to carry liferafts. Since most accidents occur during the landing and takeoff phases, it is important that the slides on the narrow-body aircraft be modified to provide a means to avoid immersion into water. At a minimum, the slides on the narrow-body aircraft should include handholds and quick release attachments while research continues in developing slides that meet flotation performance requirements.

The NTSB Safety Study concluded that, although most current regulations and equipment are based on planned water impacts (ditchings) of transport aircraft, these incidents are extremely rare. Although inadvertent water impacts occur more often than planned ones, they are also very rare. The potential of an inadvertent water impact for extended overwater operations is almost the same for any overwater operation because there are at least 179 fully certified airports in the U.S. with significant bodies of water within 5 miles. These airports are not required to develop plans for handling water impacts.

## 5. AIRPORTS SURVEY.

A survey of worldwide airports was conducted to determine the number of airports surrounded by significant bodies of water, as well as to estimate of the number of operations occurring over water. This database was generated as a result of the significant proportion of worldwide accidents occurring on or near the airport. According to Boeing's worldwide operations summary (reference 7), which covered the years 1959 to 1992, 69.1 percent of all accidents occur during the flight phases within close proximity to the airport, specifically takeoff, initial climb, final approach, and landing. For those airports located adjacent to significant bodies of water as LaGuardia Airport is, an additional risk is posed to the occupants of the airplane, and proper survival equipment should be provided. The worldwide airport database used in this survey contained 156 U.S. airports serving as large, medium, or small transport service hubs, as well as 100 foreign airports which provide international service. The foreign airports represented the following regions:

a. Canada and North Atlantic,
b. Caribbean and South America,
c. Europe, North Africa, and Middle East,
d. Africa,
e. Eastern Europe and Asia, and
f. Pacific, Australia, and Antarctica.

The airport database (appendix D) was generated in two steps. First, the airport listings and corresponding operational statistics were obtained. The U.S. data were obtained from the FAA's annual Airport Activity Statistics of Certified Route Air Carriers publication (reference 8), and worldwide data were obtained from ICAO's Digest of Airport Traffic Statistics publication (reference 20). The ICAO data included only those airports whose operations included international service. Next, the airports' surrounding environment was analyzed using the National Oceanic and Atmospheric Administrations' monthly U.S. and worldwide Terminal Procedures publication (references 9 and 10). These procedures detail both runway and approach configurations for major airports, as well as depicting the presence of significant surrounding bodies of water. A "significant body of water" is defined as any body of water encompassing an area of one-quarter square mile or greater. Because of the large scale used in creating the approach plates, it was assumed that any body of water depicted on the approach plate is greater than one-quarter square mile in area. The number of approaches passing over these bodies of water were recorded in the database for each airport and were used in the generation of the overwater operations statistics.

Of the 256 airports in the database, 194 (75.8%) were found to have at least one overwater approach. This percentage was found to be slightly higher for the U.S. airports (120 of 156 = 76.9%) and slightly lower for the foreign airports (74 of 100 = 74.0%).

In calculating the airport operations and passenger statistics, the U.S. and foreign airports were treated separately. The FAA's annual Airport Activity Statistics publication tabulates "Airport Operations" (defined as either one takeoff or one landing), whereas ICAO's Digest of Airport Traffic Statistics tabulates "Aircraft Movements." These two data types and the passenger data were cross checked at identical airports, and they were not found to be equivalent. ICAO's Digest does not define Aircraft Movements.

The total number of U.S. airport operations was found to be 6.42 million, 81.7% (5.24 million) of which occurred at airports having at least one overwater approach. Note that this does not imply that 81.7% of the operations occur over water, as it is extremely difficult to determine the percentage of operations for each individual runway. A total of 439 million passengers were enplaned at U.S. airports, 363 million (82.7%) of whom were enplaned at airports having one or more overwater approaches.

Foreign airports had a total of 5.92 million operations and 480 million enplaned passengers. Airports having one or more overwater approaches had 3.98 million (67.2%) operations and 331 million (69.0%) enplaned passengers.

A summary of the results of the airport survey is shown in table 8. The results indicate that approximately 3/4 of all airports providing international service are near a significant body of water and involve at least one overwater approach.

TABLE 8. WORLDWIDE AIRPORT OPERATIONS STATISTICS SUMMARY

| | Total Airports | Airports with Overwater Approaches | Total Operations (millions) | Operations at Airports with Over-water Approaches (millions) | Total Passengers (millions) | Passengers at Airports with Over-water Approaches (millions) |
|---|---|---|---|---|---|---|
| U.S. | 156 | 120 (76.9%) | 6.42 | 5.24 (81.7%) | 439 | 363 (82.7%) |
| Foreign | 100 | 74 (74%) | 5.92 | 3.98 (67.2%) | 480 | 331 (69.0%) |
| Total | 256 | 194 (75.8%) | | | | |

## 6. CONCLUDING REMARKS.

1. By reviewing transport airplane ditching and unplanned water impact occurrences encompassing the years 1959 to 1991 the following statements can be made.

a. Approximately two-thirds of all worldwide accidents occur during those flight phases within close proximity of the airport. The majority of water related mishaps occur within close proximity of the airport during these flight phases.

b. At airports with obstacles or steep drop-offs at the end of the runway, runway overruns pose a significant threat to occupant survival.

c. Most water impact accidents involve some degree of fuselage separation and/or fuselage crush. The greatest hazard is the rate that water enters the aircraft after structural integrity is lost, which affects the passengers' ability to evacuate and make effective use of flotation devices.

d. Current emergency procedures and equipment designs are based on the assumption that transport aircraft water impacts are primarily ditchings. Only one ditching occurred from 1959 to 1991.

e. Because of the infrequency of deep water ditchings, there is limited data regarding the effectiveness of emergency evacuation procedures, equipment, and facilities in these situations.

f. Slide/raft combinations have been successfully deployed and used in the evacuation of occupants during emergency procedures. Not all slide/rafts may be available during evacuation.

g. For airports with runways bordered by bodies of water, safety areas to stop aircraft may be geographically unfeasible. For these runways, an inclined surface area (ISA) or arresting material may be a viable solution.

2. Recommendations made by the National Transportation Safety Board regarding emergency equipment design and procedures are as follows:

a. All seat cushions should be of the flotation type.

b. Because of the high percentage of water mishaps which occur in close proximity to the airport, life preservers should be made available to all passengers on all flights, regardless of extent of overwater operations.

c. The use of water activated batteries in life preserver mounted survivor locator lights could be supplemented by dry cells which would allow the wearer to manually activate the lights should water contact not be made.

d. The lifevest should be easily removed from its package in one simple procedure. Testing of the removal and donning of the lifevests should be performed under a variety of conditions, including environmental extremes.

e. The effectiveness of megaphones should be evaluated under a variety of conditions, including possible submergence in water.

f. Adequate water rescue facilities, equipment, and training should exist at airports located near significant bodies of water. Rescue operations should be tested and proven effective for the weather conditions expected, including extremes such as ice covered bodies of water.

g. The design of infant lifevests should be such that it provides buoyancy as well as protection against the effects of hypothermia.

h. Nonfrangible obstacles located within the runway extended safety area introduce a hazard to passenger survivability in the event of runway overruns. These obstacles should be redesigned.

3. Based on the worldwide airport survey the following statement can be made: approximately 3/4 of all worldwide transport airports which have international flights involve approaches which occur over significant bodies of water.

## 7. REFERENCES.

1. "Commercial Jet Transport Crashworthiness," Boeing Company, DOT/FAA/CT/82-68, March 1982.

2. "Transport Aircraft Crash Dynamics," Lockheed-California Company, DOT/FAA/CT/82-69, March 1982.

3. "Transport Aircraft Accident Dynamics," McDonnell-Douglas Corp., DOT/FAA/RD/74-12.

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# APPENDIX A — FAR 1, 25, 121, AND 125 DEFINITIONS

DEFINITIONS (1.1)

"Extended overwater operation" means —

a. with respect to aircraft other than helicopters, an operation over water at a horizontal distance of more than 50 nautical miles from the nearest shoreline; and

b. with respect to helicopters, an operation over water at a horizontal distance of more than 50 nautical miles from the nearest shoreline and more than 50 nautical miles from an off-shore heliport structure.

DITCHING (25.801)

a. The probability of immediate injury to occupants must be minimized. The chances for occupant egress must be maximized.

b. The probable behavior of aircraft in a ditching situation must be shown by one of the following methods:

1. Model testing
2. Comparison of airplanes with similar configurations.

c. The flotation time and trim of the aircraft must allow occupants to leave the aircraft and enter liferafts.

d. The external doors and windows must be able to withstand the probable maximum local pressures.

EMERGENCY EVACUATION (25.803)

a. Each crew and passenger area must have emergency means to allow rapid evacuation in crash landings with the landing gear extended as well as with the landing gear retracted and considering the possibility of the airplane being on fire.

b. (Reserved)

c. For airplanes having a seating capacity of more than 44 passengers, it must be shown that the maximum seating capacity, including the number of crewmembers required by the operating rules for which certification is requested, can be evacuated from the airplane to the ground under simulated emergency conditions within 90 seconds. Compliance with this requirement must be shown by actual demonstration using the test criteria outlined in appendix J of this part unless the Administrator finds that a combination of analysis and testing will provide data equivalent to that which would be obtained by actual demonstration.

EMERGENCY EXITS (25.807)

a. If the aircraft has less than nine seats, one exit above the waterline must be provided on each side of the aircraft.

b. If the aircraft has 10 seats or more, one Type III exit must be provided for every unit of 35 seats with a minimum of two exits with one on each side of the aircraft.

c. If it is impractical to locate the exits above the waterline on the side of the aircraft, an equal number of overhead hatches of dimensions not less then Type III exits must be provided.

(Type III exits are defined as rectangular openings with minimum width of 20 inches and minimum height of 36 inches.)

SAFETY EQUIPMENT (25.1411)

a. Liferafts

1. Must have enough liferafts to accommodate the maximum number of occupants that the aircraft is designed to carry.

2. Must be stowed near exits such that they can be launched during ditching.

3. Liferafts which are released manually or automatically must have a static line attached to it.

4. Stowage must allow rapid detachment and removal of raft for use at other than intended exits.

b. Life Preserver

1. There must be at least one life preserver for each occupant.

2. The life preserver must be within easy reach of each seated passenger.

c. Life Line

1. Must be provisions to store the life line.

2. At least one life line must be attached to each side of the fuselage.

3. The life lines must be arranged in such a way that occupants are able to remain on the wing after ditching.

DITCHING EQUIPMENT (25.1415)

a. Each liferaft and life preserver must be certified.

b. The buoyancy and seating capacity of the rafts must accommodate all occupants in the event of the loss of the largest raft available.

c. Each raft must have a trailing line and static line to hold the raft near the aircraft. But if the aircraft becomes totally submerged, the lines must release.

d. Approved survival equipment must be included in each life raft.

e. There must be at least one emergency locator transmitter in one liferaft.

f. If airplane is not certified for ditching, an approved flotation device must be provided for each occupant.

DEMONSTRATION OF EMERGENCY EVACUATION PROCEDURES (121.291)

a. Each ditching certified operator must demonstrate a simulated ditching.

b. During the simulation, each life raft must be removed from stowage, at least one liferaft launched and inflated, and the crewmembers assigned to the inflated life raft must display and describe the use of the required emergency equipment.

EMERGENCY EQUIPMENT FOR EXTENDED OVER-WATER OPERATIONS (121.339)

a. A life preserver with survivor locator light for each occupant.

b. Enough liferafts of a rated capacity and buoyancy to accommodate each occupant. All occupants must be accommodated for in the event of a loss of the largest rated liferaft.

c. One pyrotechnic signaling device for each liferaft.

d. Survival type emergency locator transmitter.

e. The above mentioned equipment must be easily accessible in the event of a ditching.

f. A survival kit must be present in each liferaft.

EMERGENCY FLOTATION MEANS (121.340)

a. Every large airplane must have life preservers or another approved type of flotation device for each occupant.

b. Flotation devices are not required if the operator can prove that the water over which it will fly is of such size and depth that flotation means would not be required for each occupant.

CREWMEMBER EMERGENCY TRAINING (121.417)

a. Training must be provided on equipment used in ditching and evacuation.

b. Training must be provided in using the emergency exits with the evacuation slide/raft pack attached.

c. Instructions in handling ditching and other emergency situations must be given.

d. An emergency ditching simulation drill must be run with occupants evacuation through an installed evacuation slide.

e. Once each 24 months, the crew must demonstrate their proficiency in the above mentioned training and other procedures related to ditching.

CRITERIA FOR DEMONSTRATION OF EMERGENCY EVACUATION PROCEDURES (APPENDIX D TO PART 121)

a. The ditching demonstration must assume that daylight hours exist outside the airplane.

b. If passengers are required to assist in launching liferafts, they must be present.

c. A stand at each emergency exit must be placed as to simulate the water level of the airplane following a ditching.

d. Each evacuee must don a lifevest.

e. Each liferaft must be launched and inflated.

f. Each evacuee must enter a liferaft and crewmembers must display and describe the emergency equipment aboard the liferaft.

g. A mockup or floating device must simulate the passenger compartment.

h. Mockup - A life-size mockup of the interior representing the current airplane. Operation of the emergency exits must closely simulate those of the real airplane.

i. Floating Device - The device must simulate the passenger compartment of the airplane. It must be equipped with the same survival equipment as the plane.

EMERGENCY EQUIPMENT: EXTENDED OVERWATER OPERATIONS (125.209)

a. The following equipment is required and must be installed in conspicuously marked and easily accessible locations for extended overwater operations:

1. An approved life preserver equipped with an approved survivor locator light, or an approved flotation means, for each occupant of the aircraft. The life preserver or other flotation means must be easily accessible to each seated occupant.

2. If a flotation means other than a life preserver is used, it must be readily removable from the airplane.

3. Enough approved life rafts (with proper buoyancy) to carry all occupants of the airplane, and at least the following equipment for each raft clearly marked for easy identification:

(i) One canopy (for sail, sunshade, or rain catcher)
(ii) One radar reflector (or similar device)
(iii) One life raft repair kit
(iv) One bailing bucket
(v) One signaling mirror
(vi) One police whistle
(vii) One raft knife
(viii) One $CO_2$ bottle for emergency inflation
(ix) One inflation pump
(x) Two oars
(xi) One 75-foot retaining line
(xii) One magnetic compass
(xiii) One dye marker
(xiv) One flashlight having at least two size " D" cells or equivalent
(xv) At least one approved pyrotechnic signaling device
(xvi) A 2-day supply of emergency food rations supplying at least 1,000 calories a day for each person
(xvii) One sea water desalting kit for each two persons that raft is rated to carry, or two pints of water for each person the raft is rated to carry
(xviii) One fishing kit
(xix) One book on survival appropriate for the area in which the airplane is operated

b. At least one of the life rafts must be equipped with a survival type emergency locator transmitter that meets TSO C91. Batteries used in this transmitter must be replaced (or recharged, if the batteries are rechargeable) when the transmitter has been in use for more than 1 cumulative hour, and also when 50 percent of their useful life (or for rechargeable batteries, 50 percent of their useful life of charge), as established by the transmitter manufacturer under TSO C91 has expired. The new expiration date for the replacement or recharged batteries must be legibly marked on the outside of the transmitter. The battery useful life or useful life of charge requirements of this paragraph do not apply to batteries (such as water-activated batteries) that are essentially unaffected during storage intervals.

## CRITERIA FOR DEMONSTRATION OF EMERGENCY EVACUATION PROCEDURE (APPENDIX B TO PART 125)

a. The ditching demonstration must assume that daylight hours exist outside the airplane and that all required crewmembers are available for the demonstration.

b. If the certificate holder's manual requires the use of passengers to assist in the launching of liferafts, the needed passengers must be aboard the airplane and participate in the demonstration according to the manual.

c. A stand must be placed at each emergency exit and wing with the top of the platform at a height simulating the water level of the airplane following a ditching.

d. After the ditching signal has been received, each evacuee must don a lifevest according to the certificate holder's manual.

e. Each liferaft must be launched and inflated according to the certificate holder's manual and all other required emergency equipment must be placed in rafts.

f. Each evacuee must enter a liferaft and the crewmembers assigned to each liferaft must indicate the location of emergency equipment aboard the raft and describe its use.

g. Either the airplane, a mockup of the airplane, or a floating device simulating a passenger compartment must be used.

1. If a mockup of the airplane is used, it must be a life-size mockup of the interior and representative of the airplane currently used by or proposed to be used by the certificate holder and must contain adequate seats for use of the evacuees. Operation of the emergency exits and the doors must closely simulate that on the airplane. Sufficient wing area must be installed outside the over-the-wing exits to demonstrate the evacuation.

2. If a floating device simulating a passenger compartment is used, it must be representative, to the extent possible, of the passenger compartment of the airplane used in operations. Operation of the emergency exits and the doors must closely simulate operation on that airplane. Sufficient wing area must be installed outside the over-the-wing exits to demonstrate the evacuation. The device must be equipped with the same survival equipment as is installed on the airplane, to accommodate all persons participating in the demonstration.

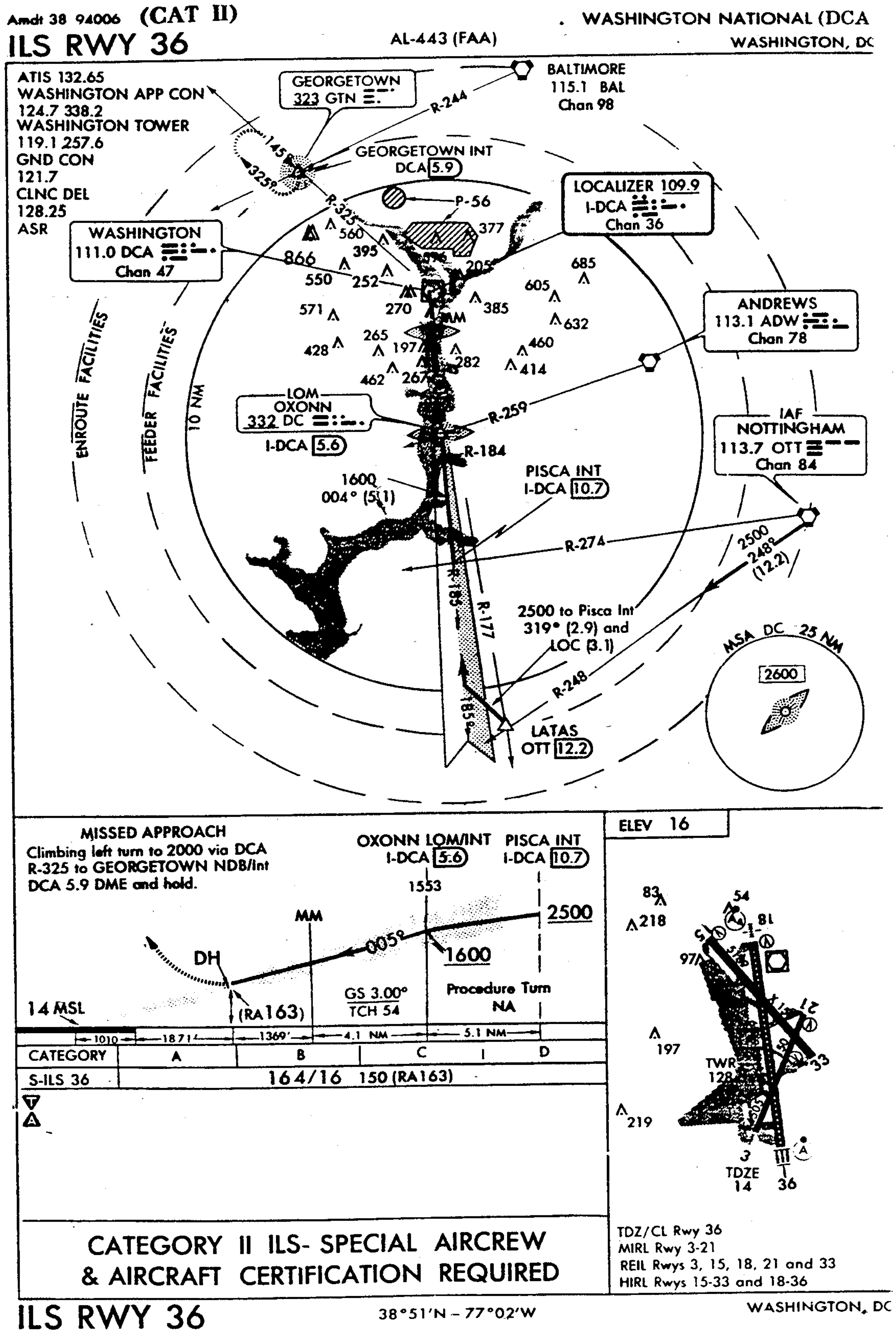



FIGURE B-1. WASHINGTON NATIONAL AIRPORT APPROACH PLATE (reference 9)

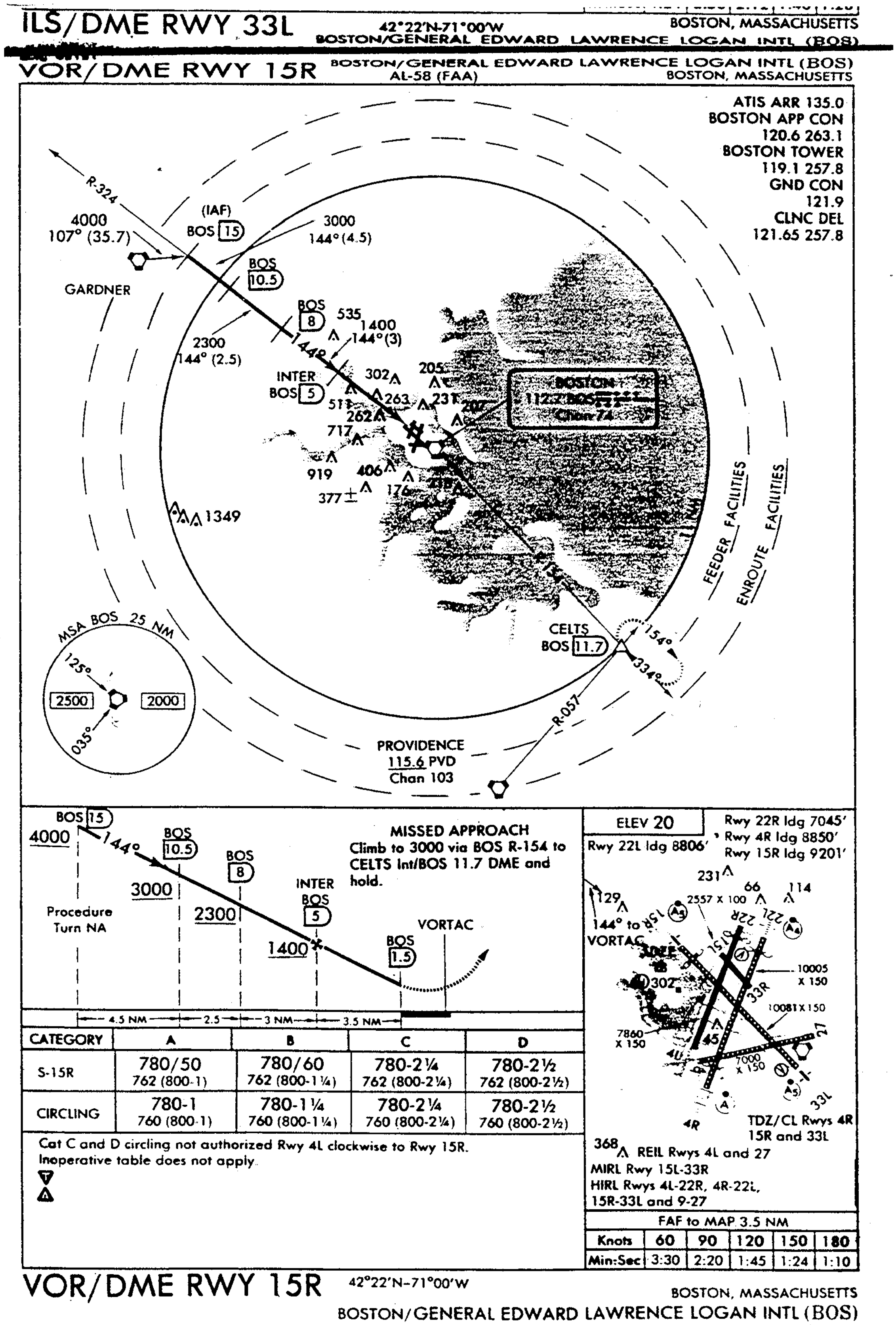



FIGURE B-2. BOSTON-LOGAN INTERNATIONAL AIRPORT APPROACH PLATE (reference 9)

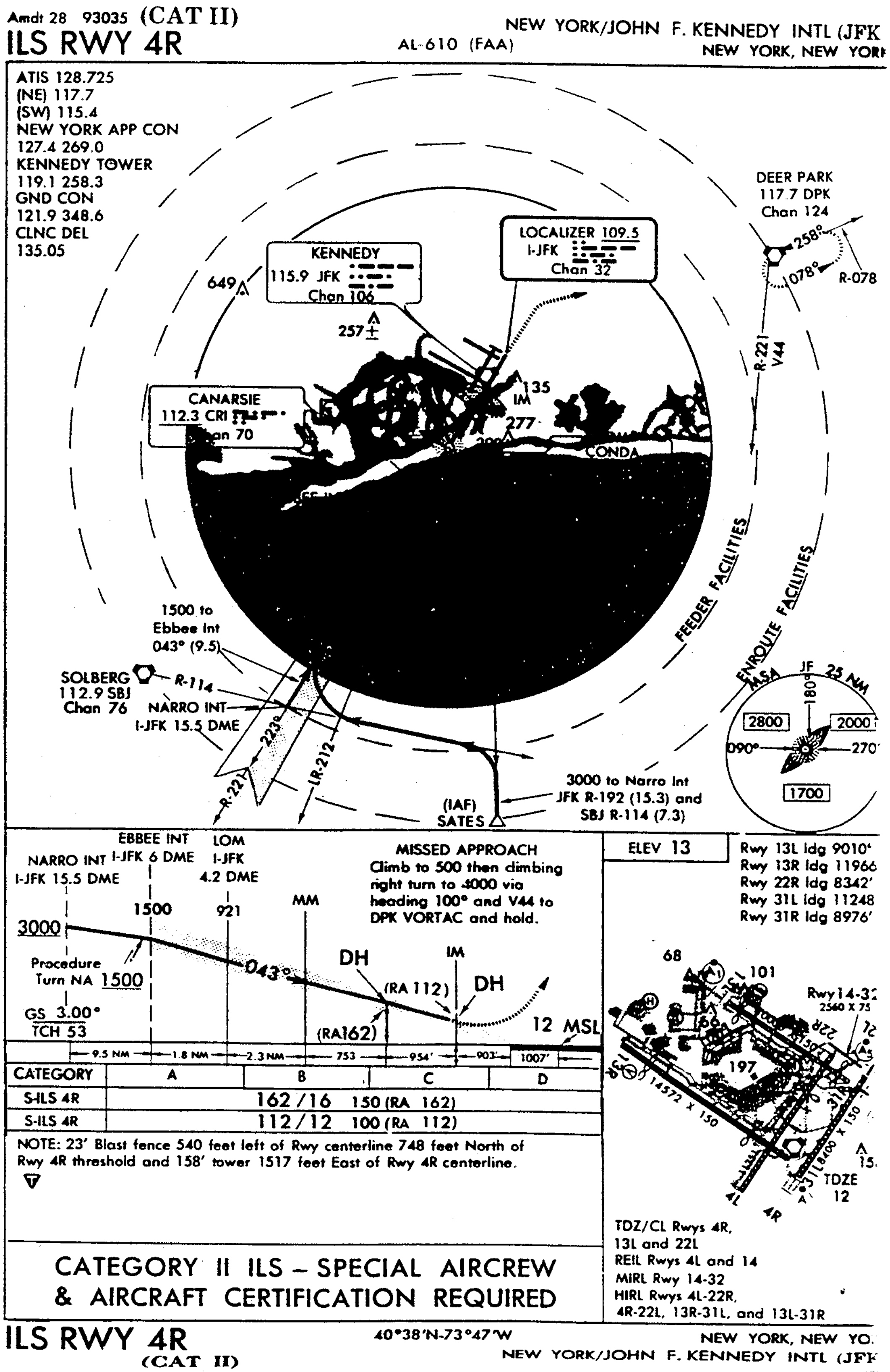
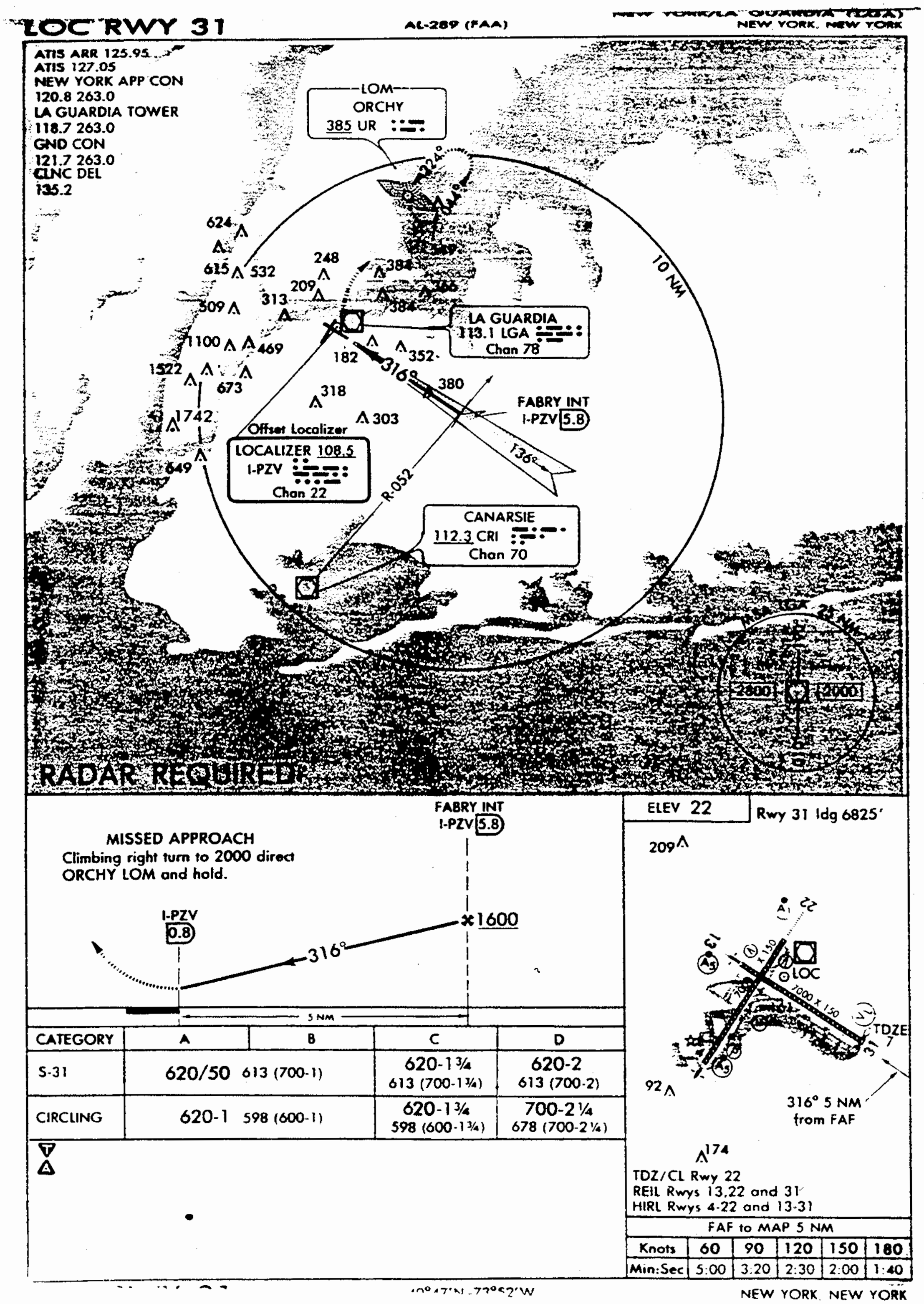



FIGURE B-3. JFK INTERNATIONAL AIRPORT APPROACH PLATE (reference 9)




| CATEGORY | A | B | C | D |
|---|---|---|---|---|
| S-31 | 620/50 | 613 (700-1) | 620-1¾ 613 (700-1¾) | 620-2 613 (700-2) |
| CIRCLING | 620-1 | 598 (600-1) | 620-1¾ 598 (600-1¾) | 700-2¼ 678 (700-2¼) |

| FAF to MAP 5 NM | | | | | |
|---|---|---|---|---|---|
| Knots | 60 | 90 | 120 | 150 | 180 |
| Min:Sec | 5:00 | 3:20 | 2:30 | 2:00 | 1:40 |

FIGURE B-4. LAGUARDIA AIRPORT APPROACH PLATE (reference 9)

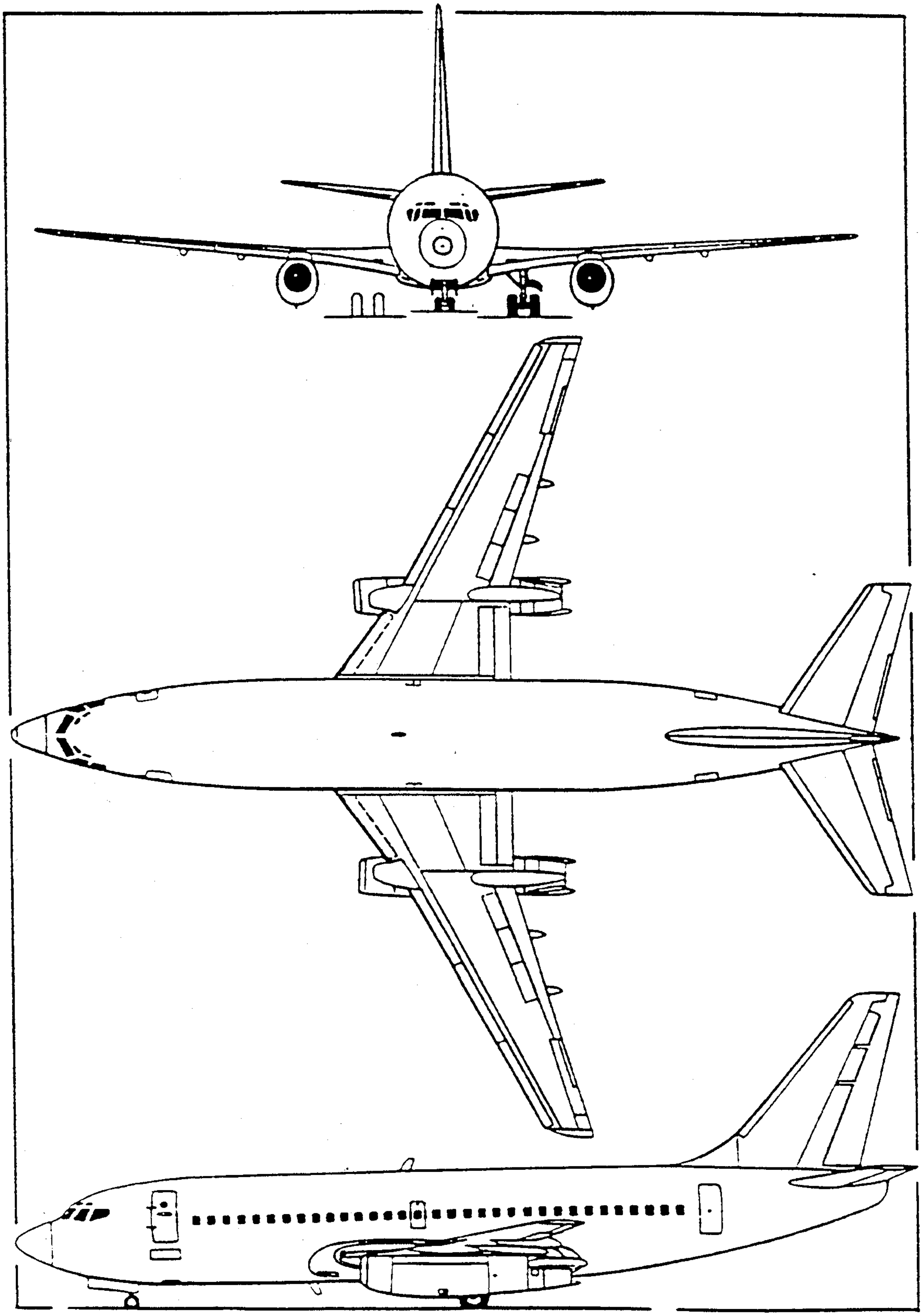


FIGURE C-1. BOEING 737-200 CUTAWAY/THREE-VIEW DRAWING
(reference 21)

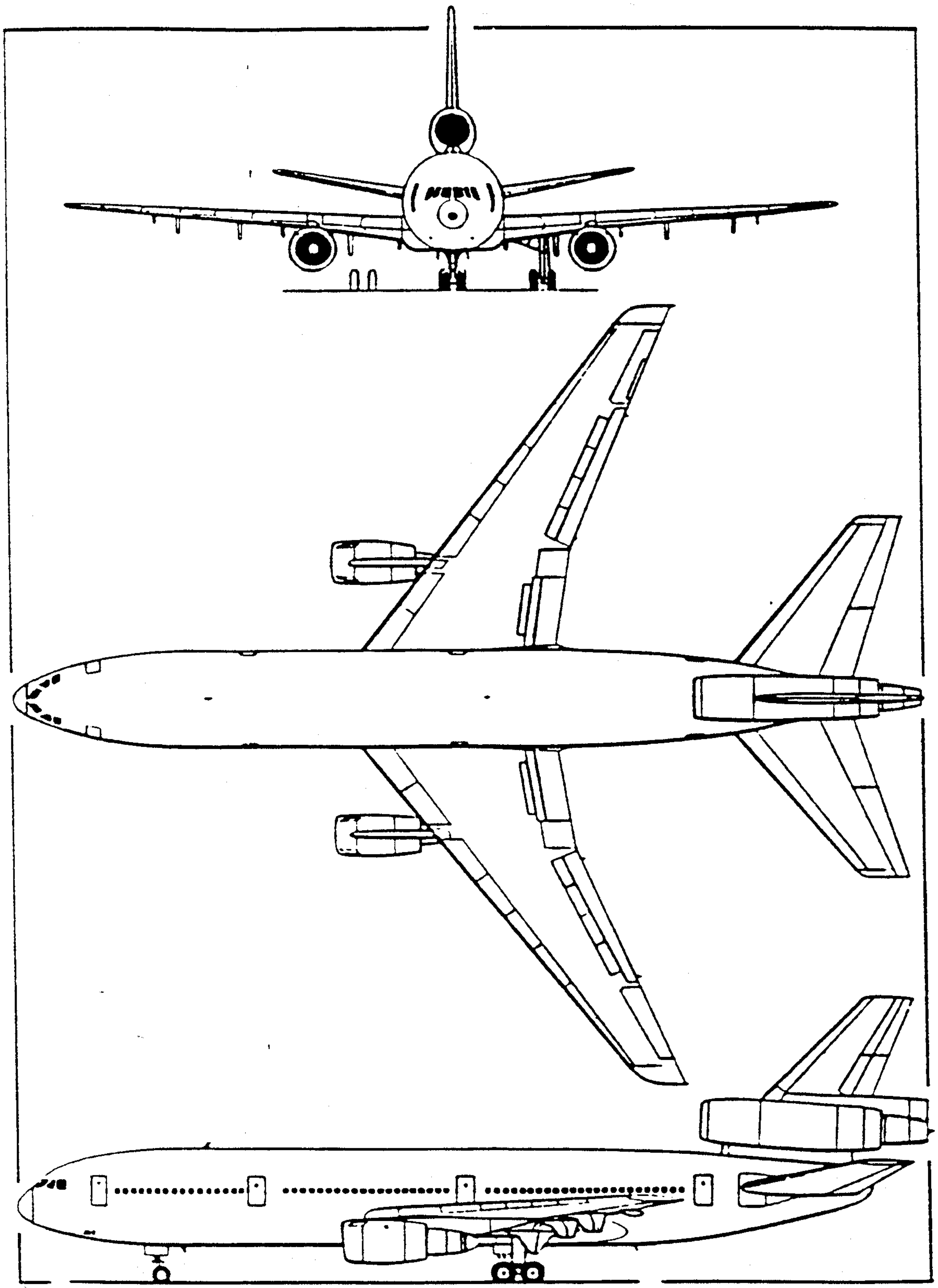


FIGURE C-2. DC-10 CUTAWAY/THREE-VIEW DRAWING

(reference 21)

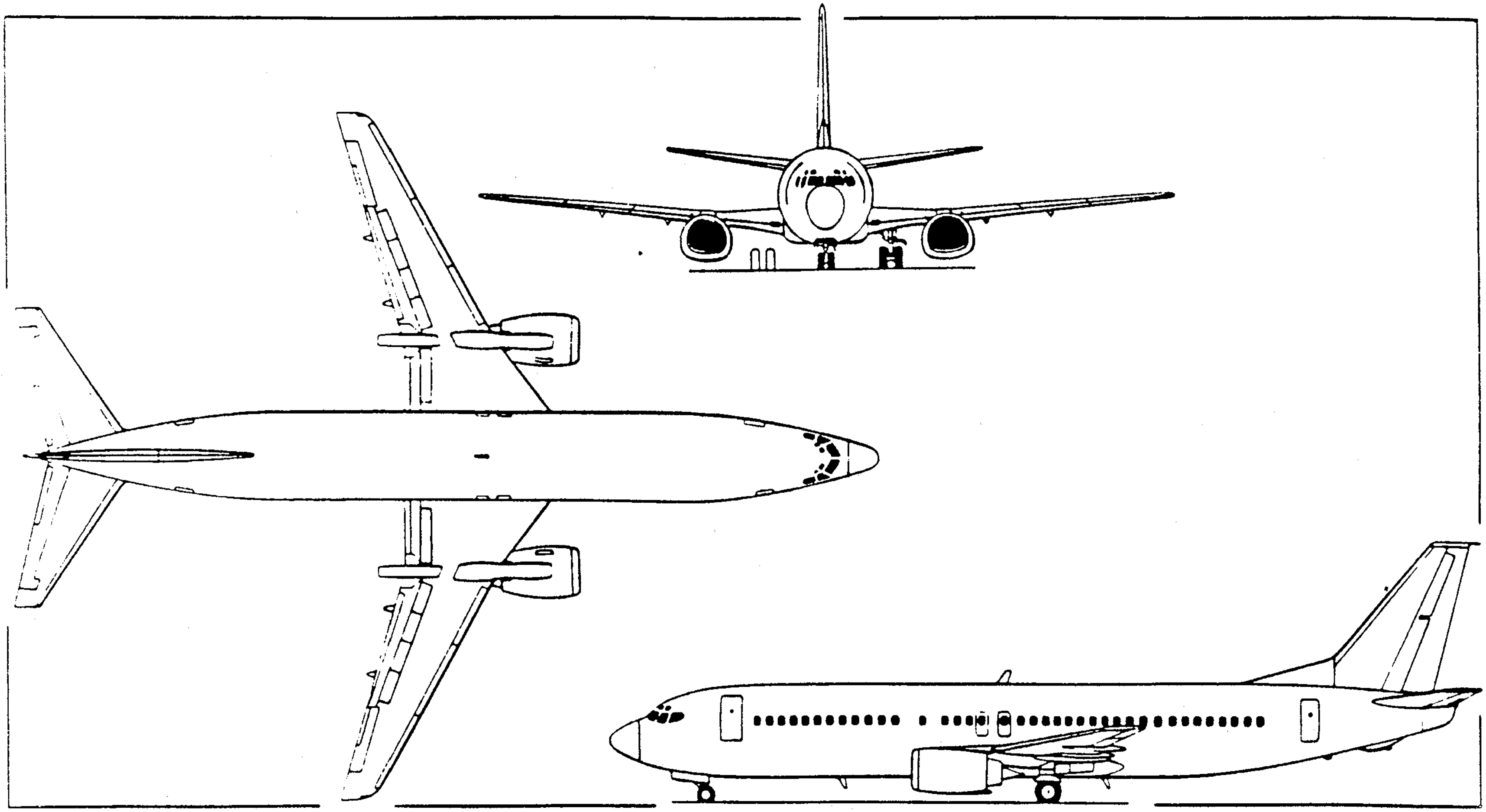


FIGURE C-3. BOEING 737-400 CUTAWAY/THREE-VIEW DRAWING (reference 21)

# APPENDIX D — AIRPORT DATABASE

| AIRPORT | LOCATION | NUM_RWYS | MIN_LENGTH | MAX_LENGTH | OW_APP | OPERATIONS | PASSENGERS |
|---|---|---|---|---|---|---|---|
| ADAMS FIELD | LITTLE ROCK, AR | 3 | 5124 | 7200 | 6 | 15154 | 950540 |
| ADDISON | DALLAS/FT. WORTH, TX | 1 | 7201 | 7201 | 1 | 1 | |
| AKRON-CANTON | AKRON/CANTON, OH | 3 | 5600 | 7598 | 1 | 5606 | 230249 |
| ALBANY COUNTY | ALBANY, NY | 2 | 5999 | 7200 | 3 | 15007 | 878372 |
| ALBUQUERQUE INT'L | ALBUQUERQUE, NM | 4 | 5130 | 13775 | 1 | 34138 | 2384647 |
| ALLEN C THOMPSON FIELD | JACKSON-VICKSBURG,MS | 1 | 5000 | 5000 | 1 | 9001 | 391018 |
| ALLENTOWN-BETHLEHEM-EASTON | ALLEN/BETH/EASTON,PA | 3 | 2392 | 7600 | 0 | 7744 | 349358 |
| AMARILLO AIR TERMINAL | AMARILLO/BORGER, TX | 2 | 7901 | 13502 | 0 | 6616 | 435297 |
| BALTIMORE-WASHINGTON INT'L | BALTIMORE, MD | 4 | 5000 | 9519 | 4 | 73300 | 4420425 |
| BANGOR INT'L | BANGOR, ME | 1 | 11439 | 11439 | 2 | 3095 | |
| BIRMINGHAM MUNI | BIRMINGHAM, AL | 2 | 4856 | 10000 | 0 | 20112 | 1001983 |
| BLUE GRASS | LEXNGTN/FRANKFORT,K | 2 | 3501 | 7002 | 0 | 7811 | 291634 |
| BOEING FIELD-KING CTY. INT'L | SEATTLE, WA | 2 | 3710 | 10001 | 1 | 43 | 2154 |
| BOISE AIR TERMINAL/GOWEN FLD | BOISE, ID | 2 | 7400 | 9763 | 0 | 16802 | 525092 |
| BOSTON-LOGAN INT'L | BOSTON, MA | 5 | 2557 | 10081 | 5 | 114153 | 9549585 |
| BRADLEY INT'L | WINDSOR LOCKS, CT | 3 | 5141 | 9502 | 2 | 31850 | 2312455 |
| BUCHANAN FIELD | SAN FRANCISCO, CA | 4 | 2768 | 4601 | 1 | 1286 | 49532 |
| BURKE LAKEFRONT | CLEVELAND, OH | 2 | 5200 | 6198 | 1 | 1 | 0 |
| BURLINGTON INT'L | BURLINGTON, VT | 2 | 3602 | 7807 | 2 | 7507 | 306489 |
| CAPE KENNEDY REGIONAL | MELBBOURNE, FL | 3 | 3002 | 9481 | 2 | 5838 | 360126 |
| CEDAR RAPIDS MUNI | CED RAP/IOWA CITY,IA | 2 | 5450 | 8600 | 2 | 7753 | 341142 |
| CHICAGO-O'HARE INT'L | CHICAGO, IL | 7 | 5341 | 13000 | 4 | 322430 | 25636383 |
| CLARENCE E HANCOCK | SYRACUSE, NY | 2 | 7501 | 9003 | 1 | 29514 | 1166598 |
| CLEVELAND-HOPKINS INT'L | CLEVELAND, OH | 4 | 6015 | 8998 | 3 | 76988 | 3836050 |
| COLUMBIA METROPOLITAN | COLUMBIA, SC | 2 | 7000 | 8602 | 1 | 13531 | 512759 |
| CORPUS CHRISTI INT'L | CORPUS CHRISTI, TX | 2 | 6081 | 7508 | 2 | 6651 | 423498 |
| DALLAS FORT WORTH INT'L | DALLAS/FORT WORTH,TX | 7 | 4000 | 11388 | 4 | 266737 | 22899267 |
| DAYTONA BEACH REGIONAL | DAYTONA BEACH, FL | 3 | 3197 | 7500 | 1 | 7514 | 490336 |
| DES MOINES MUNI | DES MOINES, IA | 3 | 3202 | 9001 | 1 | 12144 | 658619 |
| DETROIT CITY | DETROIT, MI | 2 | 4025 | 5147 | 1 | 6828 | 362655 |
| DETROIT MET. WAYNE COUNTY | DETROIT, MI | 4 | 8500 | 12000 | 1 | 134929 | 9903078 |
| DONALDSON CENTER | GREENVILLE,SPRTBG,SC | 1 | 5184 | 5184 | 1 | 60 | 0 |
| DOUBLE EAGLE II | ALBUQUERQUE, NM | 2 | 5999 | 7398 | 0 | 1 | 0 |
| DOUGLAS MUNI | CHARLOTTE, NC | 1 | 5000 | 5000 | 0 | 120210 | 7076954 |
| DULLES INT'L | WASHINGTON, D.C. | 3 | 10501 | 11501 | 2 | 80651 | 4448592 |
| EL PASO INT'L | EL PASO, TX | 3 | 5493 | 11012 | 0 | 28333 | 1673243 |
| ELLINGTON FIELD | HOUSTON, TX | 3 | 4000 | 9000 | 2 | 1188 | 18967 |
| EPPLEY AIRFIELD | OMAHA, NE | 3 | 4060 | 8500 | 3 | 19952 | 994132 |
| FRESNO AIR TERMINAL | ESNO, CA | 2 | 7206 | 9222 | 1 | 20879 | 393442 |
| FT.LAUDERDALE-HOLLYWOOD INT'L | FT.LAUDERDALE, FL | 3 | 5276 | 9000 | 1 | 46584 | 3875357 |
| GENERAL MITCHELL FIELD | MILWAUKEE, WI | 5 | 3163 | 9690 | 2 | 39724 | 1915390 |
| GREATER BUFFALO INT'L | BUFFALO&NIAGARAFS,NY | 2 | 5376 | 8102 | 1 | 30554 | 1637293 |
| GREATER CINCINNATI | CINCINNATI, OH | 3 | 3817 | 6102 | 1 | 65533 | 3907625 |
| GREATER PITTSBURGH INT'L | PITTSBURGH, PA | 4 | 8039 | 11500 | 3 | 125276 | 7912394 |
| GREENSBORO-HIGH PT-WINSTN REG. | GRNSBORO,H PT,WST,NC | 2 | 6380 | 10000 | 1 | 23519 | 894532 |
| GREENVILLE/SPARTANBURG | GREENVILLE,SPRTBG,SC | 1 | 7600 | 7600 | 0 | 23519 | 894532 |
| HARRISBURG INT'L | HARRISBURG/YORK, PA | 1 | 9501 | 9501 | 2 | 10537 | 437341 |
| HILO INT'L | HILO, HI | 2 | 5600 | 9800 | 2 | 10868 | |
| AIRPORT | LOCATION | | | | | | |
| HOLLYWOOD-BURBANK | LA/BURBNK/LNG BCH,CA | 2 | 6066 | 6885 | 0 | 30444 | 1698739 |
| HONOLULU INT'L | HONOLULU, HI | 4 | 6952 | 12357 | 4 | 92659 | 9002217 |
| HOPKINS INT'L | CLEVELAND, OH | 4 | 6015 | 8998 | 5 | 76988 | 3836050 |

| AIRPORT | LOCATION | NUM_RWYS | MIN_LENGTH | MAX_LENGTH | OW_APP | OPERATIONS | PASSENGERS |
|---|---|---|---|---|---|---|---|
| HOUSTON INTERCONTINENTAL | HOUSTON, TX | 4 | 6038 | 12001 | 2 | 104249 | 7543899 |
| INDIANAPOLIS INT'L | INDIANAPOLIS, IN | 3 | 7604 | 10005 | 0 | 53471 | 2601839 |
| JACKSONVULLE INT'L | JACKSONVILLE, FL | 2 | 7700 | 8000 | 2 | 24585 | 126677 |
| JAMES M COX/DAYTON INT'L | DAYTON, OH | 3 | 7000 | 10900 | 0 | 36966 | 1845160 |
| JOE FOSS FIELD | SIOUX FALLS, SD | 3 | 3152 | 8999 | 0 | 6466 | 226436 |
| JOHN F. KENNEDY INT'L | NEW YORK, NY | 5 | 2560 | 14572 | 5 | 74659 | 9687068 |
| KAHULUI AIRPORT | KAHULUI, HI | 2 | 4990 | 7000 | 2 | 29624 | 2094390 |
| KANSAS CITY INT'L | KANSAS CITY, MO | 2 | 9500 | 10801 | 2 | 52781 | 3358116 |
| KE-AHOLE | KAILUA-KONA,HI,HI | 1 | 6500 | 6500 | 1 | 14800 | 977274 |
| KENT COUNTY | GRAND RAPIDS, MI | 3 | 3400 | 10000 | 2 | 13086 | 614280 |
| LA GUARDIA | NEW YORK, NY | 2 | 7000 | 7000 | 4 | 129670 | 10725465 |
| LAKEFRONT | NEW ORLEANS, LA | 3 | 3094 | 6879 | 6 | 1 | 0 |
| LAMBERT-ST. LOUIS INT'L | ST. LOUIS, MO | 5 | 3008 | 11019 | 5 | 135089 | 9332091 |
| LIHUE | LIHUE, KAUAI, HI | 2 | 6500 | 6500 | 2 | 18704 | 1264738 |
| LOGAN FIELD | BILLINGS, MT | 4 | 3800 | 10528 | 0 | 8741 | 237699 |
| LONG BEACH | LA/BURBNK/LNG BCH,CA | 5 | 4267 | 10000 | 1 | 14443 | 692995 |
| LONG ISLAND-MACARTHUR | ISLIP, LONG ISLD, NY | 4 | 3212 | 7000 | 2 | 7001 | 422400 |
| LOS ANGELES INT'L | LOS ANGELES, CA | 4 | 8925 | 12091 | 4 | 213302 | 18438056 |
| LOVE FIELD | DALLAS/FT. WORTH, TX | 3 | 6149 | 8800 | 1 | 39481 | 2882836 |
| LOVELL FIELD | CHATTANOOGA, TN | 2 | 5000 | 7401 | 1 | 5327 | 239746 |
| LUBBOCK REGIONAL | LUBBOCK, TX | 3 | 2869 | 11500 | 0 | 11574 | 611413 |
| LUIS MUNOZ MARIN INT'L | SAN JUAN, PR | 2 | 8016 | 10002 | 2 | 39208 | 3618090 |
| LUKEN FIELD | CINCINNATI, OH | 3 | 3817 | 6102 | 2 | 1 | 0 |
| MADISON COUNTY | HUNTSVILLE, AR | 1 | 3600 | 3600 | 1 | 9880 | 381668 |
| MAHLON SWEET FIELD | EUGENE, OR | 2 | 5221 | 8000 | 2 | 8074 | 224658 |
| MCCARRAN INT'L | LAS VEGAS, NV | 4 | 5001 | 12636 | 2 | 92196 | 7796218 |
| MCGHEE TYSON | KNOXVILLE, TN | 2 | 9000 | 9008 | 2 | 10228 | 477768 |
| MEACHAM FIELD | DALLAS/FT. WORTH, TX | 3 | 4001 | 7501 | 0 | 1 | 0 |
| MEMPHIS INT'L | MEMPHIS, TN | 3 | 8400 | 9319 | 1 | 94420 | 3887208 |
| METROPOLITAN | NASHVILLE, TN | 4 | 6011 | 9240 | 4 | 57474 | 3404243 |
| METROPOLITAN OAKLAND INT'L | OAKLAND,CA | 4 | 3366 | 10000 | 3 | 45986 | 2670788 |
| MIAMI INT'L | MIAMI, FL | 3 | 9355 | 13000 | 3 | 106858 | 9226103 |
| MICHIANA REGIONAL | SOUTH BEND, IN | 2 | 6000 | 7099 | 0 | 6630 | 224050 |
| MID-CONTINENT AIRPORT | WICHITA, KA | 3 | 6301 | 10300 | 2 | 13772 | 561432 |
| MIDLAND REGIONAL | MIDLAND/ODESSA, TX | 4 | 4245 | 9501 | 0 | 8675 | 580905 |
| MIDWAY | CHICAGO, IL | 5 | 3859 | 6521 | 2 | 64465 | 3547040 |
| MILLARD | OMAHA, NE | 1 | 3800 | 3800 | 0 | 12 | 0 |
| MILLER INT'L | MCALLEN, TX | 2 | 2648 | 7108 | 0 | 2180 | |
| MINNEAPOLIS/ST.PAUL INT'L | MINNEAPOLIS, MN | 3 | 8200 | 10000 | 3 | 114872 | 8837228 |
| CONCORD MUNICIPAL | MANCHESTER/CONCRD,NH | 3 | 3499 | 6009 | 2 | 6344 | 267963 |
| MUNICIPAL/BAER FIELD | FORT WAYNE, IN | 2 | 8500 | 12000 | 0 | 7851 | 242000 |
| NEW ORLEANS INTL-MOISANT FIELD | NEW ORLEANS, LA | 3 | 4542 | 10080 | 4 | 49121 | 3361062 |
| NEWARK INT'L | NEWARK, NJ | 3 | 6800 | 9300 | 3 | 130286 | 9853925 |
| NIAGARA FALLS INT'L | NIAGARA FALLS, NY | 3 | 3973 | 9125 | 0 | 0 | |
| NORFOLK REGIONAL | NORFOLK/VABCH/PTS,VA | 2 | 4876 | 9000 | 2 | 26495 | 1254846 |
| AIRPORT | LOCATION | | | | | | |
| OAKLAND MERTOPOLITAN INT'L | SAN FRANCISCO, CA | 4 | 3366 | 10000 | 3 | 45986 | 2670788 |
| ONTARIO INT'L | ONTARIO, CA | 2 | 10200 | 12200 | 0 | 40925 | 2640734 |
| ORLANDO INT'L | ORLANDO, FL | 3 | 10000 | 12004 | 3 | 84924 | 7677769 |
| PAGE FIELD | FORT MYERS, FL | 2 | 4997 | 6401 | 2 | 2 | 0 |
| PAL-WAUKEE | CHICAGO, IL | 4 | 3228 | 5137 | 1 | 1 | |
| PALM BEACH INT'L | WEST PALM BEACH, FL | 3 | 3152 | 7989 | 2 | 29363 | 2609138 |
| PALM SPRINGS MUNI | INDIO/PALM SPRING,CA | 2 | 4952 | 8500 | | 9270 | 353294 |

| AIRPORT | LOCATION | NUM_RWYS | MIN_LENGTH | MAX_LENGTH | OW_APP | OPERATIONS | PASSENGERS |
|---|---|---|---|---|---|---|---|
| PALMDALE, PROD.FLT.TESTS.INST. | PALMDALE, CA | 2 | 12000 | 12002 | 0 | 1579 | |
| PENSACOLA REGIONAL | PENSACOLA, FL | 2 | 4700 | 7002 | 2 | 8765 | 394222 |
| PETERSON FIELD | COLORADO SPRINGS, CO | 3 | 8668 | 13500 | 0 | 10903 | 551507 |
| PHILADELPHIA INT'L | PHILADELPHIA, PA | 3 | 5460 | 10499 | 7 | 105830 | 6970820 |
| PHOENIX SKY HARBOR INT'L | PHOENIX, AZ | 2 | 10300 | 11001 | 0 | 148342 | 10727494 |
| PORT COLUNBUS INT'L | COLUMBUS, OH | 3 | 3908 | 10250 | 2 | 29986 | 1685100 |
| PORTLAND INT'L | PORTLAND, OR | 3 | 7000 | 11011 | 4 | 69578 | 3025345 |
| PORTLAND INT'L JETPORT | PORTLAND, ME | 2 | 5000 | 6800 | 1 | 8712 | 472393 |
| PUEBLO MEMORIAL AIRPORT | PUEBLO, CO | 3 | 4073 | 10496 | 0 | 1804 | |
| QUAD-CITY | MOLINE, IL | 3 | 4909 | 8507 | 1 | 6286 | 220093 |
| RALEIGH-DURHAM | RALEIGH/DURHAM, NC | 3 | 3700 | 10000 | 3 | 66211 | 4361369 |
| RENO INT'L | RENO, NV | 3 | 5992 | 10002 | 2 | 21609 | 1343619 |
| RICHARD BYRD FLYING FIELD | RICHMOND, VA | 3 | 5316 | 8999 | 2 | 20443 | 864381 |
| RIO GRANDE VALLEY INT'L | HARLINGEN, TX | 4 | 5745 | 8300 | 0 | 7444 | 529042 |
| ROANOKE MUNI | ROANOKE, VA | 2 | 5800 | 6802 | 1 | 7143 | 224595 |
| ROBERT MUELLER MUNI | AUSTIN, TX | 3 | 3999 | 7269 | 1 | 31494 | 2054955 |
| ROCHESTER-MONROE COUNTY | ROCHESTER, NY | 3 | 4403 | 8001 | 1 | 25132 | 1154747 |
| BATON ROUGE MET, RYAN FIELD | BATON ROUGE, LA | 3 | 3799 | 7000 | 2 | 8837 | 423808 |
| SACREMENTO METROPOLITAN | SACREMENTO, CA | 2 | 8600 | 8600 | 0 | 39723 | 1737096 |
| SAIPAN INT'L | SAIPAN, MARIANA ISLS | 1 | 8700 | 8700 | 1 | 4037 | 279019 |
| SALT LAKE CITY INT'L | SALT LAKE CITY, UT | 3 | 5295 | 12003 | 3 | 77368 | 5388178 |
| SAN ANTONIO INT'L | SAN ANTONIO, TX | 3 | 5519 | 7505 | 0 | 39740 | 2593896 |
| SAN DIEGO-LINDBERGH FIELD | SAN DIEGO, CA | 2 | 4439 | 9400 | 1 | 70156 | 5260907 |
| SAN FRANCISCO INT'L | SAN FRANCISCO, CA | 4 | 7001 | 11870 | 3 | 172007 | 13474929 |
| SAN JOSE MUNI | SAN JOSE, CA | 3 | 5295 | 12003 | 2 | 49173 | 3128393 |
| SANTA BARBARA | SANTA BARBARA, CA | 3 | 4179 | 6049 | 2 | 9999 | 226472 |
| SANTA MARIA PUBLIC | SANTA BARBARA, CA | 2 | 5269 | 6300 | 1 | 1740 | 6213 |
| SARASOTA-BRADENTON | SARASOTA/BRANDNTN,FL | 2 | 5004 | 7003 | 1 | 15765 | 989935 |
| SAVANNAH INT'L | SAVANNAH, GA | 2 | 7001 | 9351 | 2 | 11089 | 520881 |
| SEATTLE-TACOMA INT'L | SEATTLE, WA | 2 | 9425 | 11900 | 3 | 122226 | 7385594 |
| SHREVEPORT REGIONAL | SHREVEPORT, LA | 2 | 6201 | 8351 | 2 | 7656 | 257229 |
| SNOHOMISH COUNTY PAINE FIELD | EVERETT, WA | 3 | 3000 | 9010 | 1 | 11 | |
| SOUTH PADRE ISLAND INT'L | BROWNSVILLE/HRLGN,TX | 3 | 3749 | 7400 | 3 | 1 | 0 |
| SOUTHWEST | FORT MYERS, FL | 1 | 8400 | 8400 | 1 | 22210 | 1712679 |
| SPOKANE INT'L | SPOKANE, WA | 2 | 8199 | 9000 | 1 | 25315 | 747329 |
| ST.PETERSBURG/CLWTR INT'L | ST.PTSBG/CLWTR, FL | 4 | 4000 | 8500 | 2 | 2 | 118 |
| STANDIFORD FIELD | LOUISVILLE, KY | 2 | 7249 | 10001 | 1 | 21813 | 937645 |
| STAPLETON INT'L | DENVER, CO | 6 | 4871 | 12000 | 0 | 154067 | 11961839 |
| STOCKTON METROPOLITAN | STOCKTON, CA | 2 | 2996 | 8650 | 0 | 3601 | |
| SYRACUSE-HANCOCK INT'L | SYRACUSE, NY | 2 | 7501 | 9003 | 1 | 29514 | 1166598 |
| TALLAHASSEE MUNI | TALLAHASSEE, FL | 2 | 6066 | 8000 | 0 | 9193 | 381840 |
| AIRPORT | LOCATION | | | | | | |
| TAMPA INT'L | TAMPA, FL | 3 | 6998 | 11002 | 3 | 64396 | 4781020 |
| THEODORE FRANCIS GREEN STATE | PROVIDENCE, RI | 3 | 4535 | 7166 | 3 | 16890 | 1060719 |
| TRI CITY | SAG/BY CTY/MDLND, MI | 2 | 6400 | 8002 | 1 | 3952 | 219310 |
| TRUAX FIELD | MADISON, WI | 4 | 3390 | 9005 | 2 | 8926 | 425563 |
| TUCSON INT'L | TUCSON, AZ | 3 | 7000 | 10994 | 0 | 20201 | 1263509 |
| TULSA INT'L | TULSA, OK | 3 | 6101 | 10000 | 2 | 24975 | 1483037 |
| WASHINGTON NAT'L | WASHINGTON, DC | 3 | 4505 | 6869 | 6 | 97043 | 7034693 |
| WAYNE COUNTY | DETROIT, MI | 4 | 8500 | 12000 | 1 | 134929 | 9903078 |
| WILL ROGERS WORLD | OKLAHOMA CITY, OK | 4 | 2975 | 9802 | 2 | 25347 | 1519518 |
| WILLIAM B HOBBY | HOUSTON, TX | 4 | 5149 | 7602 | 1 | 61387 | 3972327 |
| WILLIAM B. HARTSFIELD INT'L | ATLANTA, GA | 4 | 9000 | 11889 | 0 | 285693 | 22665665 |

| AIRPORT | LOCATION | NUM_RWYS | MIN_LENGTH | MAX_LENGTH | OW_APP | OPERATIONS | PASSENGERS |
|---|---|---|---|---|---|---|---|
| WILLOW RUN | DETROIT, MI | 5 | 6511 | 7294 | 1 | 4241 | 35 |
| PORT BOUET | ABIDJAN, COTE D'IVOIRE (IVORY COAST) | 1 | 8858 | 8858 | 1 | 14000 | 0 |
| ABU DHABI | ABU DHABI,UNTD ARAB EM | 1 | 13452 | 13452 | 1 | 33500 | 1234000 |
| KOTOKA INTL | ACCRA, GHANA | 1 | 9800 | 9800 | 1 | 7200 | 762000 |
| ADELAIDE | ADELAIDE, AUSTRALIA | 2 | 5420 | 8294 | 2 | 21000 | 2047000 |
| SCHIPHOL | AMSTERDAM, NETHERLANDS | 5 | 6608 | 11329 | 5 | 202300 | 16198000 |
| ESENBOGA | ANKARA, TURKEY | 2 | 12303 | 12303 | 0 | 23700 | 1973000 |
| ANTALYA | ANTALYA, TURKEY | 2 | 9809 | 11155 | 2 | 17800 | 2107000 |
| ATHINAI | ATHENS, GREECE | 2 | 10335 | 11483 | 2 | 112700 | 10077000 |
| BANGKOK INTL | BANGKOK, THAILAND | 2 | 11483 | 12140 | 2 | 109000 | 14329000 |
| BARCELONA | BARCELONA, ESPANA (SPAIN) | 2 | 8924 | 10197 | 2 | 117700 | 9041000 |
| E.CORTISSOZ | BARRANQUILLA, COLOMBIA | 1 | 9843 | 9843 | 0 | 26000 | 620000 |
| P.S.W. GOLDSON | BELIZE, BELIZE | 1 | 7100 | 7100 | 1 | 22000 | 266000 |
| TEGEL | BERLIN, GERMANY | 2 | 7953 | 9918 | 2 | 100900 | 6709000 |
| TEGEL/TEMPELHOF | BERLIN, GERMANY | 2 | 6867 | 6943 | 2 | 0 | 0 |
| BIRMINGHAM | BIRMINGHAM, UNTD KINGDOM | 2 | 4314 | 7398 | 0 | 65700 | 3492000 |
| ELDORADO | BOGOTA, COLOMBIA | 1 | 12467 | 12467 | 0 | 95000 | 4500000 |
| BREMEN | BREMEN, GERMANY | 1 | 6673 | 6673 | 1 | 27500 | 1096000 |
| GRANTLEY ADAMS | BRIDGETOWN, BARBADOS | 1 | 11000 | 11000 | 1 | 33100 | 1320000 |
| BRISBANE | BRISBANE, AUSTRALIA | 2 | 5577 | 11680 | 2 | 49200 | 4539000 |
| BRUXELLES NATL | BRUSSELS, BELGIQUE (BELGIUM) | 3 | 9790 | 11936 | 0 | 176900 | 0 |
| EZEIZA | BUENOS AIRES, ARGENTINA | 3 | 7215 | 10827 | 0 | 22100 | 2375000 |
| CAIRO INTL | CAIRO, EGYPT | 3 | 10279 | 13123 | 1 | 70200 | 7159000 |
| CALGARY INTL | CALGARY, CANADA | 3 | 6200 | 12675 | 2 | 0 | 0 |
| CHEJU INTL | CHEJU, REP OF KOREA | 2 | 6573 | 9859 | 2 | 42200 | 5811000 |
| KOELN-BONN | COLOGNE, GERMANY | 3 | 6122 | 12467 | 0 | 73800 | 3027000 |
| KATUNAYAKE | COLOMBO, SRI LANKA | 1 | 10991 | 10991 | 1 | 11700 | 1472000 |
| DARWIN | DARWIN, AUSTRALIA | 2 | 5000 | 10906 | 2 | 6600 | 483000 |
| INDIRA GANDHI | DELHI, INDIA | 2 | 9229 | 12500 | 0 | 46100 | 5407000 |
| DHAHRAN INTL | DHAHRAN, SAUDI ARABIA | 3 | 8268 | 12008 | 3 | 25400 | 2540000 |
| DOHA INTL | DOHA, QATAR | 1 | 15000 | 15000 | 1 | 20000 | 1100000 |
| DOUALA | DOUALA, CAMEROUN | 1 | 9350 | 9350 | 1 | 0 | 0 |
| DUBLIN | DUBLIN, IRELAND | 3 | 4449 | 8650 | 0 | 95000 | 5492000 |
| DUSSELDORF | DUSSELDORF, GERMANY | 2 | 5348 | 9842 | 1 | 135100 | 11559000 |
| FARO | FARO, PORTUGAL | 1 | 8169 | 8169 | 1 | 22500 | 2629000 |
| FRANKFURT-MAIN | FRANFURT-MAIN, GERMANY | 3 | 13123 | 13123 | 0 | 308500 | 28713000 |
| FREEPORT INTL | FREEPOT, BAHAMAS | 1 | 10997 | 10997 | 1 | 34000 | 1228000 |
| AIRPORT | LOCATION | | | | | | |
| COINTRIN | GENEVA, SUISSE (SWITZERLAND) | 1 | 12795 | 12795 | 1 | 91500 | 5489000 |
| GLASGOW | GLASGOW, UNTD KINGDOM | 2 | 3570 | 8720 | 1 | 70700 | 4286000 |
| LA AURORA | GUATEMALA, GUATEMALA | 1 | 9800 | 9800 | 0 | 0 | 0 |
| SIMON BOLIVAR | GUYAQUIL, ECUADOR | 2 | 9843 | 11483 | 2 | 23500 | 1182000 |
| HAT YAI | HAADYAI, TAILAND | 1 | 10006 | 10006 | 0 | 7500 | 557000 |
| HAMBURG | HAMBURG, GERMANY | 2 | 10663 | 12027 | 2 | 109700 | 6666000 |
| HANOVER | HANNOVER, GERMANY | 3 | 2559 | 12467 | 2 | 50300 | 2700000 |
| HONG KONG INTL | HONG KONG, UNTD KINGDOM | 1 | 10930 | 10930 | 1 | 106100 | 18688000 |
| HONALULU INTL | HONALULU, UNTD STATES | 4 | 6952 | 12357 | 4 | 251900 | 23368000 |
| IBIZA | IBIZA, ESPANA (SPAIN) | 1 | 9186 | 9186 | 1 | 20800 | 2437000 |
| ATATURK | ISTANBUL, TURKEY | 2 | 7546 | 9842 | 2 | 77400 | 6233000 |
| SOEKARNO-HATTA | JAKARTA, INDONESIA | 1 | 9843 | 9843 | 0 | 91300 | 7526000 |
| KING ABDUL AZIZ | JEDDAH, SAUDI ARABIA | 3 | 10827 | 12467 | 3 | 62700 | 7466000 |
| KARACHI INTL | KARACHI, PAKISTAN | 2 | 7500 | 10500 | 0 | 47200 | 0 |
| N'DJILI | KINSHASA, ZAIRE | 1 | 15420 | 15420 | 1 | 17200 | 525000 |

| AIRPORT | LOCATION | NUM_RWYS | MIN_LENGTH | MAX_LENGTH | OW_APP | OPERATIONS | PASSENGERS |
|---|---|---|---|---|---|---|---|
| KOTA KINABALU | KOTA KINABALU, MALAYSIA | 1 | 9800 | 9800 | 1 | 0 | 0 |
| K.LUMPUR INTL | KUALA LUMPUR, MALAYSIA | 1 | 12401 | 12401 | 0 | 0 | 0 |
| KUWAIT | KUWAIT, KUWAIT | 2 | 11152 | 11483 | 2 | 14800 | 1412000 |
| MURTALA MUHAMME | LAGOS, NIGERIA | 2 | 9006 | 12795 | 2 | 40800 | 2048000 |
| LARNACA | LARNACA, CYPRUS | 1 | 8858 | 8858 | 1 | 32600 | 2795000 |
| GATWICK | LONDON, UNTD KINGDOM | 2 | 8415 | 10364 | 0 | 189400 | 21043000 |
| HEATHROW | LONDON, UNTD KINGDOM | 3 | 6450 | 12802 | 0 | 368400 | 42635000 |
| LUXEMBOURG | LUXEMBOURG, LUXEMBOURG | 1 | 13123 | 13123 | 0 | 28200 | 973000 |
| MAASTRICHT | MAASTRICHT, NETHERLANDS | 2 | 3543 | 8202 | 0 | 11300 | 290000 |
| MADRAS | MADRAS, INDIA | 2 | 6680 | 10050 | 2 | 15400 | 1768000 |
| SEYCHELLES INTL | MAHE, SEYCHELLES | 1 | 9825 | 9825 | 1 | 18600 | 0 |
| MALAGA | MALAGA, ESPANA (SPAIN) | 1 | 10500 | 10500 | 1 | 44500 | 4744000 |
| MARS.-PROVINCE | MARSEILLES, FRANCE | 2 | 7776 | 11483 | 2 | 61000 | 4674000 |
| SIR S.RAMGOOLAM | MAURITIUS, MAURITIUS | 1 | 8497 | 8497 | 1 | 11400 | 876000 |
| MELBOURNE INTL | MELBOURNE, AUSRALIA | 2 | 5200 | 6303 | 0 | 78600 | 7618000 |
| MALPENSA | MILAN, ITALIE (ITALY) | 2 | 11532 | 12844 | 2 | 22800 | 2099000 |
| MOI INTL | MOMBASA, KENYA | 2 | 4134 | 10991 | 2 | 8200 | 738000 |
| CARRASCO | MONTEVIDEO, URUGUAY | 3 | 5577 | 8858 | 3 | 0 | 0 |
| SHEREMETYEVO | MOSCOW, RUSSIAN FED'N | 2 | 11608 | 12139 | 2 | 104400 | 9314000 |
| SEEB INTL | MUSCAT, OMAN | 1 | 11762 | 11762 | 1 | 0 | 0 |
| JOMO KENYATTA | NAIROBI, KENYA | 1 | 13507 | 13507 | 0 | 21800 | 1569000 |
| NADI | NANDI, FIJI | 2 | 7000 | 10500 | 2 | 25500 | 785000 |
| COTE D'AZUR | NICE, FRANCE | 2 | 9678 | 9711 | 2 | 120000 | 5475000 |
| NUERNBERG | NIREMBERG, GERMANY | 1 | 8858 | 8858 | 0 | 36100 | 1443000 |
| FORNEBU | OSLO, NORWAY | 1 | 10449 | 10449 | 1 | 104500 | 6356000 |
| PENANG | PENANG, MALAYSIA | 1 | 11000 | 11000 | 1 | 0 | 0 |
| PERTH INTL | PERTH, AUSTRALIA | 3 | 5233 | 11299 | 1 | 22500 | 2259000 |
| PHUKET INTL | PHUKET, TAILAND | 1 | 9843 | 9843 | 1 | 14800 | 1721000 |
| JACKSONS | PORT MORESBY, PAPUA N.GUINEA | 2 | 6800 | 9022 | 2 | 35700 | 745000 |
| MARISCAL SUCRE | QUITO, ECUADOR | 1 | 10236 | 10236 | 1 | 18100 | 1552000 |
| GUARARAPES INTL | RECIFE, BRAZIL | 1 | 9846 | 9846 | 0 | 34800 | 1387000 |
| KING KHALED INTL | RIYADH, SAUDI ARABIA | 2 | 13779 | 13779 | 0 | 57100 | 6430000 |
| ROTTERDAM | ROTTERDAM, NETHERLANDS | 1 | 7218 | 7218 | 1 | 14700 | 297000 |
| AIRPORT | LOCATION | | | | | | |
| ALEXAN.HAMILTON | SAINT CROIX, UNTD STATES | 1 | 7612 | 7612 | 1 | 0 | 0 |
| CYRIL E.KING | SAINT THOMAS, UNTD STATES | 1 | 7000 | 7000 | 1 | 0 | 0 |
| RAMON VULLEDA | SAN REDRO SULA, HONDURAS | 1 | 9202 | 9202 | 1 | 9000 | 263000 |
| ARTURO MERINO B | SANTIAGO, CHILE | 1 | 10499 | 10499 | 0 | 26200 | 1750000 |
| DE LAS AMERICAS | SANTA DOMINGO, DOMINICAN REPUBLIC | 1 | 11002 | 11002 | 1 | 0 | 0 |
| KIMPO INTL | SEOUL, REP. OF KEREA | 2 | 10500 | 11811 | 2 | 113200 | 16821000 |
| SHANNON | SHANNON, IRELAND | 2 | 5643 | 10499 | 2 | 21900 | 937000 |
| CHANGI | SINGAPORE, SINGAPORE | 2 | 13123 | 13123 | 2 | 98100 | 14406000 |
| SOLA | STAVANGER, NORWAY | 2 | 7874 | 8366 | 2 | 38500 | 1313000 |
| STUTTGART | STUTTGART, GERMANY | 1 | 8366 | 8366 | 1 | 77300 | 4285000 |
| KINGSFORD INTL | SYDNEY, AUSTRALIA | 2 | 8298 | 12999 | 2 | 110100 | 11227000 |
| TONCONTIN | TEGUCIGALPA, HONDURAS | 1 | 6073 | 6073 | 0 | 7100 | 366000 |
| BEN GURION INTL | TEL AVIV, ISRAEL | 3 | 5840 | 12396 | 2 | 24700 | 3630000 |
| NEW YORK TOKYO INTL | TOKYO, JAPAN | 3 | 8200 | 10335 | 3 | 115900 | 19257000 |
| LESTER PEARSON | TORONTO, CANADA | 3 | 9500 | 11050 | 1 | 321400 | 18950000 |
| VANCOUVER INTL | VANCOUVER, CANADA | 2 | 7300 | 11000 | 2 | 203100 | 7601000 |