= **DRAFT** =

EASA Analysis of Water Impact Events

(17.01.17)

(Appendix updated 18.04.17)

1. Approach & Assumptions

2. Data Sources & References

3. Data Analysis

4. Conclusions & Recommendations

Appendix – Water Impact Events

*This paper is written to support the activities within the ARAC TACDWG on the subject of ditching. It may not reflect the final EASA views, and may not address all aspects, but is intended to provide further direction to the discussions.*

1. Approach & Assumptions

A review of water impact events from 1970 until now has been conducted, using the data sources and references described in section 2. The events identified and investigated are listed in the Appendix to this paper.

This review has been limited to “large aeroplanes” / ”transport category airplanes”, i.e those aircraft certified against JAR-25/CS-25, CAR 4b/Part 25 or similar codes used in Canada, Brasil, Russia, etc.

Included are events that involve:

* Passenger, freighter or combi aeroplanes.

Excluded are events that involve:

* Military aircraft, or military derivatives of civil aeroplanes (such as C-47);
* Piston engine driven a/c (such as DC-3);
* Hijacks/suicides (such as Ethiopian Airlines Flight 961 (B767-200ER) in November 1996 and Japan Airlines Flight 350 (DC-8-61) in February 1982).

(Note: contrary to the above, some of the sources and references mentioned in section 2. exclude non-Western built aircraft, include piston engine driven aircraft, exclude cargo aircraft, exclude aircraft with less than 20 passengers, etc., and may therefore not be completely compatible with the data presented in the Appendix to this paper.)

2. Data Sources & References

The following data sources and references have been used in this paper:

* DOT/FAA/TC-14/8
* Website “Aviation Safety Network”
* Accident investigation reports
* Wikipedia page “Water Landing”

3. Data Analysis

Forty-one (41) water impact events have been identified (see Appendix), with identification of date, location, aircraft type/model, root cause, damage to aircraft and number of occupants / fatalities / injuries.

*Note: not for all events all of this information was readily available and has therefore not (yet) been included.*

These water impact events can be divided in the following main categories (cases):

(I) Planned ditching, or emergency landing on water: the flight crew knowingly makes an emergency landing on water, either:

(A) Prepared: the flight crew had sufficient time to fully prepare the aircraft for ditching and execute the ditching in accordance with the AFM procedures; or:

(B) Semi-prepared: the flight crew did not have sufficient time to fully prepare the aircraft for ditching and/or was not able to execute the ditching in accordance with the AFM procedures.

(II) Unplanned ditching, or inadvertent water impact: runway overshoot (at take-off or landing) or runway undershoot (at landing), where the airplane alights on water.

*Note: for future discussion, further distinction could perhaps be made between “low energy” events where the aircraft went off the runway after landing, and “high energy” events where the aircraft impacted the water directly.*

(III) The airplane is prepared for ditching, but the ditching is not executed.

Number of events identified within each category:

|  |  |
| --- | --- |
| Case | Number of occurrences |
| (I) Planned ditching / emergency landing on water | Fourteen (14) |
| 1. Prepared | One (1) |
| 1. Semi-prepared | Thirteen (13) |
| (II) Unplanned ditching / inadvertent water impact | Twenty-five (25) |
| (III) Prepared for ditching but not executed | Two (2) |
| Total: | Forty-one (41) |

Based on these data, the following can be stated:

(1) Since 1970, inadvertent water impact events (case II) have happened about twice as often as emergency landings on water (case I).

*Note: the DOT/FAA/TC-14/8 report states that the accident rates for both events appear to be roughly the same over the period 1999-2009.*

(2) For emergency landings on water (case I), in the vast majority of cases (13 out of 14) the flight crew did not have sufficient time to fully prepare the aircraft for ditching and/or was not able to execute the ditching in accordance with the AFM procedures. Fuel starvation (resulting in loss of engines thrust) and engine failure(s)/flame-out(s) were identified as being the main root causes.

For the one event identified as case IA the weather conditions were very poor and probably beyond what can be envisaged as being “optimum” ditching conditions.

When considering the existing planned / unplanned ditching certification requirements and related advisory material in relation to these events, the following main observations can be made:

(1) Although a fully prepared emergency landing on water (case IA) is a very rare event, it can not be completely disregarded. Therefore, to maximize the survivability of such an event all ditching phases/aspects should be addressed, i.e.:

1. preparation before water impact
2. water impact
3. sliding on water and coming to rest
4. flotation & evacuation
5. ditching equipage
6. AFM instructions

(2) Current ditching requirements do not address an emergency landing on water where the flight crew does not have sufficient time to fully prepare the aircraft for ditching and/or is not able to execute the ditching in accordance with the AFM procedures (case IB). Therefore, the ditching requirements need to be updated to include such a case, for which all ditching phases/aspects (a) – (f) as mentioned above should be addressed as well.

*Note: this is in line with NTSB recommendation A-10-72. The EASA Generic CRI on Ditching attempts to address these “non-optimum” conditions by requiring variation of certain ditching parameters beyond the “optimum” ones defined for a fully prepared ditching.*

(3) Inadvertent water impacts (case II) are mostly addressed via advisory material (FAA AC 25-17A). For example, there is no direct requirement to perform a flotation analysis for such an event. It seems therefore necessary to more clearly identify in the requirements what is expected from Applicants in the various water impact cases to be considered.

(4) The accidents described in the Appendix to this paper indicate that in case II considerable damage to the aircraft (e.g. break-up of fuselage) may occur. This contradicts FAA AC 25-17A that states no structural damage may be assumed. Further discussion on this point would be needed.

In section 4. these main observations (plus a few additional minor ones) are turned into recommendations for future rulemaking and/or development of (additional) advisory material.

4. Recommendations

Based on the data and analysis presented in this paper, the following objectives and recommendations / comments related to water impact events can be identified, to be addressed in the applicable requirements and/or related advisory material.

| Objective | Current text | Recommendations & Comments |
| --- | --- | --- |
| (1) Define which requirements apply to aircraft for which ditching certification is required, and which requirements apply to aircraft for which ditching certification is not required | CS 25.801 | (1) Whether ditching certification is required or not, is determined by operational requirements  (Note: these may be different between EU, US, Canada, etc.)  (2) Is reference to CS 25.1411 and CS 25.1415(a) for ditching equipage correct/sufficient? |
| (2) Overall, take (practical) design measures to minimise probability of fatalities / maximize occupant protection in case of emergency landing on water | CS 25.561    CS 25.801 | (1) Link with CS 25.561 also mentioned in EASA Generic CRI subparagraph (e)(ii), and FAA AC 25-17A. Needs to be more strongly highlighted? |
| (3) Clarify that planned ditching certification would have to include all phases/aspects:  (a) preparation before water impact  (b) water impact  (c) sliding on water and coming to rest  (d) flotation & evacuation  (e) ditching equipage  (f) AFM instructions | For (a):  *EASA Generic CRI*  The proposed optimum conditions for the approach and resulting impact must be verified to be practical by flight test panels of the applicant and the Agency.  For (b): see CS 25.563 and CS 25.801(e) below  For (c): see CS 25.801(c) below  For (d): see CS 25.801(d) and CS 25.807(i) below  For (e): see CS 25.1411 and 25.1415 below  For (f): see CS 25.1581 below | (1) Need to clarify that these phases/aspects need to be investigated for “optimum” and “non-optimum” (e.g. engine-out) conditions. |
| (4) Clarify that for unplanned ditching “only” the following is required:  (d) flotation & evacuation   1. ditching equipage 2. AFM instructions | For (d): see CS 25.801(d) and CS 25.807(i) below  For (e): see CS 25.1411 and 25.1415 below  For (f): see CS 25.1581 below | (1) Need to update requirements to clarify consideration of these 3 aspects (d)(e)(f)  (2) Need to discuss possible break-up of aircraft during these events (contrary to FAA AC 25-17A that allows assumption of no structural damage) |
| (5) Determine whether (hydrodynamic) behaviour of the aeroplane in case of an emergency landing on water is acceptable | *CS 25.801* | (1) Need to provide more guidance on “comparison with aeroplanes of similar configuration” – is comparison with 1950’s NACA reports really sufficient? |
| (6) Provide sufficient flotation time for occupants to evacuate the aircraft | *CS 25.801* | (1) Need to determine reasonably probable water conditions (salt or sweet/fresh water, calm see or certain sea state,…?)  (2) For unplanned ditching, MTOW should be used (as per FAA AC 25-17A) – with aft c.g.?  (3) Need for further guidance on:  - acceptable flotation time  - evacuation issues  => review EASA CRI’s and FAA IP’s on Unplanned Ditching  (4) Last sentence (about fuel jettisoning provisions) is unclear and appears to be incorrect (volume of displaced water provides buoyancy rather than jettisonable volume of fuel) – is about to be removed from CS-29 |
| (7) Determine structural damage due to water contact, and its effect on (hydrodynamic) behavior and flotation time (leakage) | *CS 25.563*    *CS 25.801*    *FAA AC 25-17A*  ….adjustments have been made to airplane weight and c.g. to account for loss of such items as engines, nacelles, and trailing edge  flaps on impact with the water.  *EASA Generic CRI paragraph (b)(i)(ii)(iii)*  Impact conditions: MLW / Vz = 5 fps / Vref | (1) Why only consider external doors and windows, and not the entire aircraft (as required by EASA Generic CRI)?  (2) Need to incorporate subparagraph (b) of EASA Generic CRI in CS-25 to define impact condition  (3) Need for further guidance on how to assess structural damage, e.g. on wing/body fairings  (4) Need for further guidance on acceptable means of compliance for determination of water impact loads and pressures, such as:  - FAR 25 water loads;  - data from ditching model tests;  - NLFEA (SPH/ALE) analysis. |
| (8) Provide sufficient emergency exits above waterline of sufficient size (dimensions) to timely evacuate the aircraft | *CS 25.807*    (followed by subparagraphs (1), (2) and (3)) | (1) Incorporate Generic CRI/IP on Ditching Dams?  (2) Need for further guidance on water level vs. sill height (available exits) |
| (9) Provide required ditching equipage | *CS 25.1411, CS 25.1415* | (1) Need to further clarify required ditching equipage in CS 25.1411 and CS 25.1415, also considering operational requirements |
| (10) Provide ditching and emergency evacuation instructions to flight and cabin crew | *AMC 25.1581*  Emergency procedures   * Crash landing or ditching * Emergency evacuation | (1) Need to clarify that (separate) instructions must be given for:  - “optimum” ditching conditions  - “non-optimum” ditching conditions (e.g. engine-out conditions)  - unplanned ditching |

Appendix -Water Impact Events

| Cat. | Date | | Airplane Type | Location | | Root Cause | | | Aircraft Damage & Fatalities/Injuries | | Comment(s) |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| (I)(B) | July 2011 | | Antonov 24 | Near Strezhevoy, Russia | | Fire in left engine | | | Aircraft hit underwater obstacles  Occupants: 37  Fatalities: 7 | |  |
| (I)(A) | November 2009 | | IAI 1124A | West of Norfolk Island, Australia | | After four missed approaches due to bad weather conditions the a/c was ditched | | | The main plug-type aircraft door was pushed in by the force of the water  Occupants: 6  Fatalities: 0  Injuries: 1 | | Engines set at idle, no fuel starvation |
| (I)(B) | January 2009 | | A320 | Hudson River, Weehawken, New Jersey, U.S.A. | | Dual engine failure due to bird ingestions | | | Damage to rear bottom of fuselage  Occupants: 155  Fatalities: 0  Injuries: 100 | |  |
| (I)(B) | August 2005 | | ATR72 | North East Of Palermo Airport, Italy | | Fuel starvation | | | Aircraft broke in 3 sections upon impact  Occupants: 39  Fatalities: 16 | |  |
| (I)(B) | April 2003 | | Falcon 20 | Near St. Louis airport | | Ran out of fuel | | | Aircraft damaged beyond repair  Occupants: 2  Fatalities: 0 | |  |
| (I)(B) | January 2002 | | B737-300 | Bengawan Solo River, Java, Indonesia | | Dual engine flameout during heavy precipitation and hail | | | Severe damage to aircraft belly  Occupants: 60  Fatalities: 1 | |  |
| (I)(B) | February 2001 | | SD360 | Granton Harbour, Scotland, U.K. | | Dual engine flameout due to icing | | | Aircaft destroyed  Occupants: 2  Fatalities: 2  Injuries: 0 | |  |
| (I)(B) | November 2000 | | DHC6-100 | Vancouver Harbour, British Columbia, Canada | | No.. 2 engine failure after take-off | | | Aircaft impacted the water in a nose-down, right wing-low attitude  Occupants: 17  Fatalities: 0  Injuries: 0 | |  |
| (I)(B) | January 2000 | | SD360 | Marsa El Brega, Libya | | Dual engine flameout due to icing | | | Aircraft hit water in 10 deg nose up attitude; tail broke off  Occupants: 41  Fatalities: 22 | |  |
| (I)(B) | September 1990 | | B727-247 | SE off Newfoundland, Canada | | Low fuel light | | | Aircraft was never found | |  |
| (I)(B) | October 1987 | | Dassualt Falcon 20D | Near Kevlafik, Iceland | | Fuel starvation due to strong head winds. Engines stopped 5 minutes before impact | | | Tear-off of nose cone, no structural damage to fuselage  Occupants: 6  Fatalities: 0 | |  |
| (I)(B) | March 1979 | | Nord 262 | Santa Monica Bay, Marina Del Rey, California, U.S.A. | | Auto-feather of RH propeller, crew erroneously shut down LH engine | | | Aircaft hit water smoothly, bounced twice, impacted the water in a nose down attitude, and sank almost immediately  Occupants: 7  Fatalities: 3  Injuries: ?? | |  |
| (I)(B) | May 1970 | | DC9-33F | St. Croix, Virgin Islands (U.S.) | | After several unsuccessful landing attempts, the aircraft's fuel was exhausted | | | Aircraft remained relatively intact after the water landing  Occupants: 63  Fatalities: 23  Injuries: 37 | |  |
| (I)(B) | February 1970 | | DHC6-100 | Long Island Sound, Connecticut, U.S.A. | | Fuel exhaustion | | | Occupants: 5  Fatalities: 5  Injuries: 0 | |  |
|  | |  | | |  | |  |  | |

| Cat. | Date | Airplane Type | Location | | Root Cause | | | Aircraft Damage | | | Comments(s) | |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| (II) | April 2013 | B737-800 | Ngurah Rai International Airport, Indonesia | | Undershot runway | | | Fuselage broke in two | | |  | |
| (II) | June 2011 | Antonov 26 | Libreville, Gabon | | Both propellers stopped due to hydraulic failure (?), hit water short of runway | | | The airplane came to rest submerged with the top of the tail sticking out of the water | | |  | |
| (II) | June 2004 | HS748 | Libreville airport, Gabon | | Engine no. 2 shut down due to loss of oil pressure, tried to land, overshot runway | | | Aircraft damaged beyond repair | | |  | |
| (II) | November 2002 | F27 Mk 600 | Off Manilla airport, Philipinnes | | LH engine trouble, hit water when trying to land | | Aircraft broke up and sank | | |  | | |
| (II) | April 2000 | DC-10-30F | Entebbe, Uganda | | Slid off the runway after landing | | Cockpit section separated from fuselage | | |  | | |
| (II) | February 2000 | B707-351C | Mwanza Airport | | Overshot runway during landing | |  | | |  | | |
| (II) | November 1993 | B747-400 | Kai Tak, Hong Kong | | Overran runway on landing during typhoon | |  | | |  | | |
| (II) | September 1993 | B747 | Papeete, Tahiti | | Hydroplaned during landing and overshot runway | |  | | |  | | |
| (II) | March 1992 | F28 Mk 4000 | La Guardia, New York, U.S.A. | | Ice accumulation on wings, crashed after takeoff | | Aeroplane came to rest partially inverted at the edge of Flushing Bay, and parts of the fuselage and cockpit were submerged in water | | |  | | |
| (II) | September 1989 | B737-400 | La Guardia, New York U.S.A. | | Overran runway during take-off | | A/c broke in three pieces | | |  | | |
| (II) | August 1988 | Trident 2E | Hong Kong | |  | |  | | |  | | |
| (II) | 1985 | DC-10 | Munoz Marin Airport, Puerto Rico | | Overran runway at take-off | |  | | |  | | |
| (II) | February 1984 | DC10-30 | John F. Kennedy International Airport, New York, U.S.A. | |  | |  | | |  | | |
| (II) | January 1982 | DC10-30CF | Logan International Airport, Massachusetts, U.S.A. | |  | |  | | |  | | |
| (II) | January 1982 | B737-222 | Potomac River, Washington D.C., U.S.A. | | After take-off during snowstorm without proper de-icing | |  | | |  | | |
| (II) | August 1980 | Tupolev 154B | Nouadhibou Airport, Mauritania | | Short of runaway during landing | |  | | |  | | |
| (II) | July 1979 | HS748 | Sumburgh, Shetland Islands, U.K. | |  | |  | | |  | | |
| (II) | February 1979 | F27 Mk500 | Manakau Harbour, Auckland, New Zealand | |  | |  | | |  | | |
| (II) | September 1978 | DHC6-200 | Vancouver, Canada | |  | |  | | |  | | |
| (II) | May 1978 | B727-235 | Near Pensacola, Florida, U.S.A. | | Short of runaway during foggy approach | |  | | |  | | |
| (II) | December 1977 | Caravelle 10B1R | Near Funchal, Madeira, Portugal | |  | |  | | |  | | |
| (II) | January 1976 | Sabreliner | Near Recife, PE | | Fuel shortage | | Aeroplane damaged beyond repair | | |  | | |
| (II) | July 1972 | Tu-134 | Near Moscow airport | | Both engines flamed out on final approach | |  | | |  | | |
| (II) | July 1972 | BAC1-11 | Corfu, Greece | |  | |  | | |  | | |
| (II) | July 1970 | DC8-63F | Naha Ab, Okinawa, U.S.A. | |  | |  | | |  | | |
|  | |  | |  |  |  | | |  | | |
|  | |  | |  |  |  | | |  | | |
|  | |  | |  |  |  | | |  | | |

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | | | | | | | | | | |  | | |  |  | |  | |
| Cat. | | | | | | | | | | Date | | Airplane Type | Location | | | Root Cause | | Aircraft Damage | | Comments(s) |
| (III) | | | | | | | | | | August 2001 | | A330-243 | Lajes, Azores, Portugal | | | Complete power loss due to a fuel leak | | Damage to landing gears | |  |
| (III) | | | | | | | | | | May 1983 | | L1011 | Miami, Florida, U.S.A. | | | Multiple engine failures due to oil leaks | | Damage to engines | |  |
|  | | | | | | | | | | |  | | |  |  | |  | |
|  | | | | | | | | | | |  | | |  |  | |  | |
|  | | | | | | | | | | |  | | |  |  | |  | |
|  |  |  |  |  |  |  |  |  |