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Development of new Water Landing Infrastructures and Procedures

(Versão final após defesa)

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Dissertação para obtenção do Grau de Mestre em

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Dedicatory

To my family - especially my mother, my father and my stepfather.

"The engine is the heart of an airplane but a pilot is its soul."

Walter Alexander Raleigh

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Resumo

O tema desta dissertação surge com base numa análise de acidentes históricos em território português que envolveram amaragens. A preocupação sobre este assunto foi levantada pelo Gabinete de Prevenção e Investigação de Acidentes com Aeronaves e de Acidentes Ferroviários (GPIAAF). Ao longo dos anos, têm-se verificado em Portugal acidentes deste tipo, alguns fatais, que envolvem ou deveriam ter envolvido o estudo aprofundado do processo de amaragem e suas especificidades. É, portanto, notória a existência de uma falha evidente uma falha no que concerne às características das infraestruturas dedicadas à amaragem, bem como uma eficaz avaliação de risco e preparação de tripulações no âmbito da sua formação, relativamente a este aspeto.

Desta forma, não só aborda esta dissertação uma análise de ocorrências históricas e respetivas lições aprendidas até à presente data, mas também da regulamentação existente, para que dessa forma seja possível propor novas infraestruturas de amaragem que estejam equipadas com elementos de suporte à operação e que possam servir como ajuda para as operações "normais", bem como para as situações de emergência, caso seja tomada a decisão de amarar. Assim, foram propostas duas localizações para infraestruturas deste tipo em duas barragens distintas, a barragem da Marateca e da Aguieira, a 1ª perto de Castelo Branco e a 2ª perto de Viseu. A proposta de localização destas infraestruturas tem como condição inicial estarem bem definidas e com áreas para operação balizadas, evitando-se assim os riscos de incursão nas mesmas por parte de terceiros, exclusivamente pelo desconhecimento da delimitação dessas áreas de operação restritas, bem como a existência de meios de socorro, não só para as operações normais, mas em especial em caso de acidente, diga-se, meios de busca e salvamento de reação imediata. Assim, é proposta também a capacitação da infraestrutura no "lado-terra" com hangares, placas de estacionamento e caminhos de circulação (*taxiways)* de apoio, que podem ser usados pelas aeronaves anfíbias ou de asa rotativa, sendo certo que através de cais ou rampas de acesso, as aeronaves/tripulações transitam do ambiente marítimo para o terreste. Adicionalmente, vias de acesso pelo "lado-terra", estacionamentos auto e alguns abrigos de apoio, como bares e restaurantes, por exemplo, poderão ter duplo uso, diga-se, para as atividades aéreas complementares e de resposta de emergência, bem como para fins turísticos. Também são propostos meios que garantam a segurança e a separação do "lado-ar" do "lado-terra". Todo este estudo baseia-se na regulamentação em vigor, por forma a garantir a segurança necessária e o cumprimento da mesma.

Para que a infraestrutura proposta seja viável, será necessário produzir avaliações de risco o mais rigorosas possível, que no plano da formação de tripulações levará à implementação de novos métodos de treino não só na componente teórica, mas principalmente no que se refere à instrução e treino de voo, que na nossa perspetiva, deverão ser transversais a qualquer Organização de Treino Aprovado (*Approved training Organization* - ATO). Este estudo baseia-se nos requisitos presentes em legislação internacional e nacional, que compreendem uma formação teórica e prática, bem como pontos-chave que terão de ser abordados durante a etapa de formação. Adicionalmente, estes pontos baseiam-se em pré-requisitos necessários para obtenção do averbamento da licença de piloto de aeronaves anfíbias. Para este estudo, e durante o desenvolvimento desta dissertação, apenas as fases cruciais de voo que envolvam o uso da infraestrutura mencionada, foram consideradas.

Palavras-chave

Acidentes; Aeronaves Anfíbias; Amaragem; Avaliação de Risco; Infraestrutura; Resposta a Emergências; Regulamentos; Treino de Pilotos.

Resumo Alargado

Motivação

"Amaragem: A aterragem de emergência controlada de uma aeronave na água" [1].

A aviação moderna, tal como a conhecemos atualmente, dá prioridade à segurança acima de tudo. Isto deve-se em parte a organizações ou autoridades internacionais que realizam auditorias supervisionando assim a implementação de regulamentação com vista a melhorar a Segurança de Voo na aviação em geral. Alguns exemplos são a Organização da Aviação Civil Internacional (ICAO) [2], a Administração Federal da Aviação (FAA) [3] e a Agência Europeia para a Segurança da Aviação (EASA) [4]. Para que estas organizações sejam efetivas, é necessário que os estados contratantes destas organizações tenham um forte empenhamento e total adesão às práticas e recomendações, aos regulamentos e diretivas, e que, no âmbito da Segurança de Voo tenham designado uma entidade nacional para a investigação e prevenção de acidentes com aeronaves. No caso português é o Gabinete de Prevenção e Investigação de Acidentes com Aeronaves e de Acidentes Ferroviários (GPIAAF) [5], que, sob a supervisão do Ministério das Infraestruturas, investiga acidentes e incidentes, não para determinar a culpa, mas para obter a factualidade do ocorrido, permitindo-lhe emitir alertas e recomendações. Estas são materializadas através de cada Relatório específico de cada situação, que é publicitado para conhecimento de todos. Desta forma, permite que a segurança na aviação civil avance, em defesa do interesse público, evitando que ocorrências semelhantes aconteçam no futuro [5].

Recentemente, o GPIAAF, como é seu dever de acordo com o Decreto-Lei 318/99 de 11 de agosto [6] e com o Decreto-Lei 36/2017 de 28 de março [7] que visou a sua criação por fusão[1], demonstrou publicamente a sua preocupação com a subestimação, por parte da comunidade aeronáutica portuguesa, das suas recomendações no âmbito de acidentes passados envolvendo manobras de amaragem [8]. Esta preocupação é evidenciada em palestras organizadas pelo GPIAAF sobre o tema em escolas de voo aprovadas - ATO, como por exemplo a Aeronautical Web Academy (AWA) [9], com o objetivo de sensibilizar as tripulações para que, com o acesso à informação disponível, possam apreender e reagir adequadamente a estas situações de emergência.

De acordo com o GPIAAF, há alguns mitos sobre a amaragem de aeronaves que ainda estão presentes na comunidade de pilotos. Desde *"As aeronaves de asa baixa são mais fáceis de*

[1] O Decreto-Lei 36/2017 de 28 de março, criou o GPIAAF através da fusão entre o Gabinete de Investigação de Segurança e de Acidentes Ferroviários e o Gabinete de Prevenção e Investigação de Acidentes com Aeronaves.

abandonar" e até *"É impossível evacuar a aeronave antes que ela se afunde"*; mitos estes que devem ser desconstruídos porque faltam evidências ou estatísticas que as suportem. O fator decisivo que deve ser sempre tido em consideração para a realização da manobra de amaragem é a utilização das técnicas adequadas [9]. Como tal, deve ser abordada uma nova forma de percecionar a segurança, com novos métodos de avaliação de riscos e consequente alteração dos *syllabus* na formação específica desta manobra.

A amaragem não é uma novidade em Portugal. Situado em Cabo Ruivo, em Lisboa, foi operacionalizado o primeiro aeroporto marítimo digno desse nome pois servia as operações internacionais e a base logística de hidroaviões, tendo sido uma importante porta de entrada para voos transcontinentais no início do século XX. Com o aumento do tráfego aéreo terrestre, a era dos hidroaviões de transporte de passageiros acabou, e a base de hidroaviões mencionada deixou de funcionar no final da década de 1950 [10]. No entanto, atualmente, as manobras de amaragem não são uma ocorrência rara em Portugal. Algumas companhias portuguesas, especializadas no combate a incêndios e operações agrícolas, operam habitualmente em barragens e rios de todo o país.

Uma vez que Portugal dispõe de vastos recursos hídricos, poder-se-á sugerir que a formação e treino dos pilotos (numa fase avançada), possam contemplar tais recursos, desde logo para utilizá-los em aterragens em caso de emergência. Assim, poderia ser efetuado um estudo sobre a introdução de novos locais de aterragem na água, com infraestruturas adequadas, para verificar se a segurança global do voo melhoraria na operação de aeronaves ligeiras, nos seus mais variadíssimos contextos.

Ao idealizar este tipo de infraestruturas e a sua localização, deve ser realizado um estudo do local para verificar a sua compatibilidade com o projeto a desenvolver. Alguns dos fatores que normalmente são verificados noutros países, entre muitos outros, são: os movimentos marítimos no local, incluindo as correntes e a ondulação, a relação entre a profundidade do fundo do espelho de água na pista aquática proposta e o comprimento disponível da faixa de pista de água livre e segura em relação ao tamanho e tipo de aeronave que se pretende utilizar [11]. Adicionalmente, também o espaço para instalar infraestruturas típicas, tais como: um hangar, depósitos de combustível, uma ou mais docas flutuantes, uma rampa, uma ou mais boias, pelo menos uma embarcação de assistência/salvamento e uma pequena instalação de manutenção [12] devem ser providenciadas para a criação de uma base de aviões anfíbios. Apesar de tudo isto, os pilotos só podem tirar partido destes locais se tiverem formação adequada, uma vez que a amaragem é considerada uma manobra perigosa para tripulações de voo inexperientes [9].

De acordo com os especialistas, há muitos fatores que devem ser considerados na amaragem. Entre eles: a direção e a velocidade do vento, a presença de ondulação, se presentes, a direção do seu movimento, as capacidades, o treino e a experiência do piloto. Para além disso, o desempenho e as características das aeronaves não devem ser esquecidos ou menosprezados [13]. Por conseguinte, os pilotos devem receber formação e treino específico, não só para poderem tirar partido dos locais de aterragem na água, mas também para efetuarem uma avaliação correta dos riscos na preparação de cada missão.

Objeto e Objetivos

Os objetos desta Dissertação de Mestrado são as novas infraestruturas de aterragem na água e os guias de treino de aterragem na água para aeronaves de asa fixa capazes de operar nesses locais.

Esta Dissertação de Mestrado tem 2 objetivos:

1. Projeto de infraestrutura de aterragem em 2 barragens portuguesas - Estas infraestruturas têm de cumprir todas as normas internacionais e práticas recomendadas para o projeto, operação e manutenção de aeródromos tal como referido no Anexo 14 - Volume 1 da ICAO (para aeronaves de asa fixa) [14]. Cada Anexo ICAO aborda a materialização de práticas e recomendações de cada tema relacionado com a aviação civil, sendo que o Anexo 14, se refere à generalidade dos Aeródromos. Além disso, devem também estar presentes os considerandos apresentados no Documento 9157 da ICAO - Manual de Projeto de Aeródromos [15]. Este documento fornece um guia prático pormenorizado para a aplicação das normas mencionadas no Anexo 14 nas infraestruturas a desenvolver de aterragem na água. Efetuando uma breve análise do Anexo 14 da ICAO, é possível concluir que este documento não estabelece qualquer distinção entre aeródromos terrestres e aquáticos no que se refere à superfície a partir da qual as aeronaves podem descolar e aterrar. No entanto, uma vez que as operações de aviões na água diferem significativamente das realizadas em terra, o ICAO Asia and Pacific Office emitiu um outro documento de orientação, que se torna importante analisar nesta Dissertação, uma vez que aborda os tópicos que estão em falta no Anexo 14 - Asia Pacific Regional Guidance on Requirements for the Design and Operations of Water Aerodromes for Seaplane Operations [16]. As especificações descritas neste documento centram-se nas instalações, serviços e equipamentos necessários para os aeródromos aquáticos.

Relativamente à certificação da infraestrutura proposta, o Regulamento 139/2014 da EASA [17] fornece requisitos necessários para este efeito em aeródromos localizados nos Estados Membros europeus. Ainda assim, e visto que a infraestrutura a propor não irá ultrapassar os 10000 passageiros e os 850 movimentos de carga por ano, terá apenas de cumprir com a legislação portuguesa a seguir descrita. Não obstante, é importante analisar o Regulamento por forma a perceber o *standard* europeu de certificação de aeródromos. Posto isto, a infraestrutura proposta precisa então de cumprir obrigatoriamente com o Decreto-Lei nº 186/2007 de 10 de maio [18] (que foi alterado pelo Decreto-Lei nº 55/2010 de 31 de maio [19] e mais tarde pela Lei nº 37/2023 de 31 de julho [20]). Ambos incluem requisitos adicionais relacionados com o contexto europeu e português, respetivamente. A legislação mencionada tem como objetivo estabelecer as condições de construção, certificação e exploração dos aeródromos civis nacionais e fixar os requisitos operacionais, administrativos, de segurança e de facilitação a aplicar a estas infraestruturas, bem como proceder à classificação operacional dos aeródromos civis nacionais para efeitos de planeamento aeroportuário [18]. Para que este objetivo seja alcançado, os resultados devem ser extrapolados para orientações gerais que possam ser utilizadas noutros locais adequados e necessários.

2. Desenvolvimento de um novo guia de formação e treino para manobra de aterragem na água em aeronaves de asa fixa - Este guia basear-se-á numa primeira instância no documento Easy Access Rules (EAR) for Aircrew da EASA [21]. Este documento é uma publicação que fornece uma interpretação mais abrangente e prática do Regulamento (UE) n.º 1178/2011 [22] para membros da tripulação e organizações de formação aeronáutica, por exemplo [21]. Entre outros tópicos, este regulamento aborda as normas de formação, treino e qualificação para as diferentes categorias de tripulantes de aeronaves, bem como os procedimentos e limitações operacionais para as mesmas. Em segundo lugar, o guia de formação fornecerá também a orientação da avaliação do risco de aterragem na água com base no Regulamento (UE) n.º 965/2012 [23], no AMC/GM da EASA para a Part-NCO [24] e na Part-NCC mais rigorosa [25]. Estes documentos são essenciais para garantir a conformidade com os regulamentos de aviação civil europeus, fornecendo orientações claras e meios aceitáveis de conformidade para operações aéreas seguras e padronizadas. A documentação produzida nesta dissertação também pode ser utilizada e aplicada pelas ATO como guia de formação para o treino da manobra de amaragem enquanto manobra de emergência.

Metodologia

Esta Dissertação de Mestrado compreende três fases distintas:

A primeira, pretende compreender melhor o Estado da Arte. Nesta fase, iremos apresentar a bibliografia relevante encontrada. Os relatórios do GPIAAF que se relacionem com eventos de amaragem irão ser analisados, em especial o que se refere nas suas conclusões, e recomendações. Nesta fase, iremos apresentar exemplos de locais de amaragem em operação irá ser conduzida, para perceber melhor como outros países abordam este tema. Assim, não só a pesquisa da legislação e regulamentação relativa a este aspeto deverá ser conduzida, mas também o contacto com prestadores de serviço que operam e que tem experiência no ambiente aquático, em especial de amaragem. Alguns destes operadores são contratados para operações de combate a incêndios rurais através da autoridade coordenadora, a Autoridade Nacional de Emergência e Proteção Civil (ANEPC) [26] enquanto instrumento do Estado para este efeito. Através do seu contacto, será também possível recolher informação sobre locais de amaragem que estejam a ser usados no ano corrente para manobras de recolha de água - *scooping*. Adicionalmente, a Autoridade Nacional da Aviação Civil (ANAC) também terá de ser contactada, para perceber que legislação em vigor se aplicará a este tipo de infraestruturas.

A segunda fase baseia-se na primeira. Com a informação reunida, os objetivos propostos deverão ser abordados. Irá então ser conduzida uma avaliação de regulamentação internacional, europeia e nacional, necessária para projetar e garantir a autorização de operação, quiçá a certificação destes locais de amaragem. Este será o ponto de partida para propostas de novas infraestruturas. O mesmo se aplica a conteúdo da formação e treino, que englobe também material de Avaliação de Risco.

A terceira e última fase, relaciona-se com a produção da proposta de duas infraestruturas de amaragem em duas barragens portuguesas. Esta proposta irá compreender o desenho esquemático da infraestrutura através de imagens de satélite. A decisão de colocação de cada elemento na infraestrutura será alvo de uma escolha crítica e devidamente justificada. Adicionalmente, e no que concerne ao segundo objetivo proposto, a produção de um guia de formação e treino procedimental a recorrer aquando da utilização da infraestrutura, terá por base não só regulamentação analisada na segunda fase, mas também guias produzidos por outros países que se deparam diariamente com esta realidade e que a vêm estudando, nomeadamente os países asiáticos.

Discussão de Resultados

A partir da pesquisa realizada, foi possível concluir que não há qualquer infraestrutura de amaragem em Portugal Certificada ou só Autorizada. Assim, a implementação das mesmas revela-se um desafio, tendo de ser conduzida uma análise cuidadosa às regulamentação e guias internacionais existentes e aplicáveis, adaptando-os à realidade portuguesa.

Através dos mesmos, foi possível identificar duas localizações passíveis de acolher infraestruturas deste género e passíveis de estar capacitadas com as melhores práticas e recomendações. Como tal, foram selecionadas as Barragens da Marateca e da Aguieira. Nestas, foi possível implantar as pistas de aterragem, zonas de interdição e as infraestruturas de apoio, como hangares e serviços de abastecimento, por exemplo.

Da mesma forma, também foi desenvolvido material pedagógico relacionado com o uso das infraestruturas mencionadas, que permitirá assim o seu uso operacional de forma mais segura e responsável, quer para operações planeadas e consideradas "normais", quer por situações de emergência.

Todos estes pontos garantem então que os objetivos propostos sejam cumpridos e que, poderão ser implementados nestas localizações. É importante ressalvar que estudos adicionais, nomeadamente os que estão mencionados no subcapítulo "Trabalhos Futuros", deverão ser tidos em consideração, para uma correta e eficaz operacionalização deste tipo de infraestruturas.

Conclusões

De acordo com o conteúdo desenvolvido nesta Dissertação de Mestrado, ficou demonstrado que a implementação de infraestruturas de amaragem em contexto de barragens em Portugal poderá servir, não só para retomar operações anfíbias no país, mas também servir como base operacional para operações aéreas de emergência.

Foi possível concluir, que a implementação e operacionalização de infraestruturas deste tipo, requer um planeamento cuidadoso, desde logo que respeite as normas e regulamentações em vigor, para que as operações que albergue sejam efetuadas do modo mais seguro possível - com a adição de camadas de segurança, como por exemplo a separação da área operacional da área recreativa através de marcadores visuais, ou a implementação de meios de socorro adequados, não só do "lado-terra" como também no "lado-ar". Não esquecer e ter sempre presente, como elemento inicial, as características e a performance da aeronave selecionada como a "aeronave crítica", que determinará o dimensionamento das áreas operacionais, de desobstrução de obstáculos e de suporte às operações aéreas.

Adicionalmente, também será necessária a elaboração de um guia de formação e treino procedimental para tirar o máximo partido da infraestrutura proposta, de forma segura e responsável, logo onde o risco é admissível. Estes procedimentos têm não só de ser baseados na formação prévia exigida aos pilotos por forma a obtenção do averbamento da qualificação em aeronaves anfíbias, mas também nas especificidades de cada aeronave em termos de procedimentos a realizar antes, durante e após a conclusão de cada missão.

Desta forma, concluiu-se que estas infraestruturas podem aumentar o interesse que havia outrora em operações anfíbias, mas também aumentar a segurança de voo no que concerne a aeronaves em situações delicadas de emergência. Este último caso é viável ao providenciar aos pilotos uma infraestrutura devidamente publicitada nos meios aeronáuticos e capaz de responder cabalmente a uma situação de emergência, desde logo por estarem disponíveis os meios de socorro adequados.

Trabalhos Futuros

O estudo efetuado nesta Dissertação de Mestrado teve como base o cumprimento da regulação aplicável, contudo, houve certas considerações que não foram aprofundadas, para não extravasarem os objetivos pretendidos com este estudo. Assim, é certo que existem perspetivas para trabalhos futuros, relacionadas com o trabalho desenvolvido que poderão abordar as seguintes temáticas:

1. Focar o estudo de Infraestruturas de Amaragem em contexto marítimo e fluvial, de modo a poder verificar a viabilidade do estudo em zonas com fortes correntes e ondas, bem como noutras não confinadas;
2. Estudo de impacto ambiental/ruído/aquático, para compreender a influência da implementação deste tipo de infraestruturas no ecossistema e nas zonas habitacionais limítrofes ao local escolhido;
3. Estudos de impacto económico/Análise de Custo-Benefício, para melhor compreender se o desenvolvimento de tais infraestruturas se pode traduzir em crescimento económico e em desenvolvimento regional;

4. Análise da viabilidade da proposta de Avaliação de Risco/Guia de Formação e treino junto das escolas de aviação, para desta forma avaliarem a possibilidade de inclusão de tais complementos de formação para todos os pilotos sem instrução. Adicionalmente, até mesmo obter sugestões de melhorias para uma implementação mais completa e abrangente.

Não existindo, até a data, nenhuma infraestrutura dedicada deste género em Portugal, a sua implementação poderá traduzir-se em novas oportunidades, quer para escolas de aviação, quer para a operação de combates a incêndios ou até mesmo para fins desportivos e recreativos. Todas estas possibilidades poderão e deverão ser analisadas em trabalhos futuros relacionados com esta Dissertação de Mestrado, que se pretende aberta até novos estudos e até ser um dinamizador dos mesmos.

Abstract

This Master Dissertation arises from an analysis of accidents in Portuguese territory involving water landing and ditching emergencies. The concern regarding this topic was primarily raised by Gabinete de Prevenção e Investigação de Acidentes com Aeronaves e de Acidentes Ferroviários (GPIAAF). Over the past years, Portugal has experienced several accidents of this type, some fatal, which involved or should have involved an in-depth study of the process of water landing and its specificities. It is therefore evident that there is a failure regarding the characteristics of the dedicated water landing infrastructures, as well as an effective risk assessment and flight crew training related to this aspect.

This Master Dissertation not only addresses an analysis of historical occurrences, and the lessons retrieved up from them but also the current applicable regulations, to make possible to propose new water landing infrastructures equipped with operational support elements that could assist aircrafts in regular operations as well as emergency situations, if the decision is to ditch the aircraft. For this purpose, two locations are proposed for such infrastructures at two distinct dams, Marateca and Aguieira, being the first near Castelo Branco and the latter on near Viseu. The proposed location of these infrastructures is based on the initial condition that the areas for operation are well defined and marked out, thus avoiding the risk of incursion into them by third parties who are unaware of the delimitation of these restricted areas of operation. It also accounts for the existence of means of rescue, not only for normal operations, but especially in the event of an accident, namely search and rescue means for immediate reaction. It is also proposed to build up the infrastructure on the 'land side' with hangars, parking bays and taxiways, which can be used by amphibious or rotary-wing aircraft, while aircraft/crews can move from the maritime to the land environment via docks or access ramps. Moreover, access roads, suitable car parking slots, and restaurants, for example, can have a double-use, for both complementary aerial emergency activities and for tourism purposes, for example. Means for ensuring safety and separation of "airside" to the "landside" are also proposed. This entire study is based on current regulations to ensure the necessary safety and compliance.

To ensure that the proposed infrastructure is operation viable, it will be necessary to provide for the most rigorous risk assessments possible, which in terms of crew training will lead to the implementation of new training methods, not only in the theoretical component, but mainly in terms of instruction and flight training, which should be transversal to any Approved training Organisation (ATO). This study is based on the requirements of international and national legislation, which include theoretical and practical training, as well as key points that must be addressed during the training stage. In addition, these points are based on the prerequisites needed to obtain an amphibious aircraft pilot's licence. For this study, and while developing this dissertation, only the crucial flight phases involving the use of the proposed infrastructure have been considered.

Keywords

Accidents; Amphibian Aircraft; Emergency Response; Infrastructure; Risk Assessment; Pilot Training; Regulations; Water Landing.

Index

List of Figures

List of Tables

List of Acronyms

AIA	Accident Investigation Authority
AFIS	Aerodrome Flight Information Service
AGL	Above Ground Level
ANC	Ted Stevens Anchorage International Airport (Airport Code)
ANEPC	Autoridade Nacional de Emergência e Proteção Civil
ARTCC	Air Route Traffic Control Centre
ATC	Air Traffic Control
CMA	Centros de Meios Aéreos da ANEPC
CNOS	Comando Nacional de Operações de Socorro
CRM	Crew Resource Management
EASA	European Union Aviation Safety Agency
ELT	Emergency Locator Transmitter
EPA	(United States) Environmental Protection Agency
FSS	Flight Service Station
GPIAAF	Gabinete de Prevenção e Investigação de Acidentes com Aeronaves e de Acidentes Ferroviários
ICAO	International Civil Aviation Organisation
IFR	Instrument Flight Rules
IMC	Instrument Meteorological Conditions
LHD	Lake Hood Seaplane Base (Airport Code)
MIRL	Medium Intensity Runway Lights
SAR	Search-and-Rescue
TRACON	Terminal Radar Approach Control
UN	United Nations
VMC	Visual Meteorological Conditions
VFR	Visual Flight Rules

1. Chapter 1 – Introduction

1.1. Motivation

"Ditching: The controlled emergency landing of an aircraft on water" [1].

Modern aviation, as we know it today, prioritises safety above all else. This is partly due to international organisations or authorities that aim for setting standards/practices, perform audits and oversee the implementation of regulations to improve overall flight safety around the world. Some examples are International Civil Aviation Organisation (ICAO) [2], Federal Aviation Administration (FAA) [3] and European Union Aviation Safety Agency (EASA) [4]. In order to better perform, the contracting States of these organisations must have a strong commitment and full adherence to the practices and recommendations, regulations and directives, and, within the scope of Flight Safety, they must have designated a national body for the investigation and prevention of aircraft accidents. Regarding the Portuguese case, this is the Gabinete de Prevenção e Investigação de Acidentes com Aeronaves e de Acidentes Ferroviários (GPIAAF) [5], which, under the supervision of the Portuguese Ministry of Infrastructure, investigates accidents and incidents, not to determine guilt, but to obtain the facts of what happened, allowing it to issue alerts and recommendations. These are materialised through each situation-specific report, which is publicised for everyone to see. In this way, it allows safety in civil aviation to advance, in defence of the public interest, by preventing similar occurrences to happen in the future [5].

Recently, GPIAAF, as it is their obligation according to the Portuguese Decree-Law 318/99 of August 11th [6] and with the Portuguese Decree-law 36/2017 of March 28th [7], that officialised its creation[2], has publicly shown concern at the underestimation by the Portuguese aviation community of its recommendations in the context of past accidents involving ditching manoeuvres [8]. This concern is the motivation for conferences at flight schools – ATO, such as Aeronautical Web Academy (AWA) [9], in order to raise awareness among flight crews so that, with access to information, they can better react to these emergency situations.

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[2] The Decree-Law 36/2017 of March 28th has created GPIAAF with the merge of both Gabinete Gabinete de Investigação de Segurança e de Acidentes Ferroviários e o Gabinete de Prevenção e Investigação de Acidentes com Aeronaves.

According to GPIAAF, there are some aircraft ditching myths that are still present in the pilot community. From *"Low wing aircraft are easier to ditch"* to *"It is impossible to evacuate the aircraft before it sinks"*, these ideas should be deconstructed due to the lack of evidence and statistics that do not support them. The decisive factor that should always be taken in consideration in the ditching manoeuvre is the use of proper techniques [9]. As such, a new way of perceiving safety should be addressed, with new methods for risk assessment and consequent changes to the syllabus in the specific training of this manoeuvre.

Water landing is not a novelty in Portugal. Situated in Cabo Ruivo, Lisbon, it was operationalised the first maritime airport worthy of its name because it served international operations as well as the seaplane logistics base and was an important gateway for transcontinental flights at the beginning of the XX century. With the increase of land-based air traffic, the era of seaplanes came to a conclusion, and the seaplane base mentioned ceased operation in the late 1950s [10]. However, mooring manoeuvres are not uncommon in Portugal as of today. Some Portuguese companies, that specialise on firefighting and agricultural operations, regularly operate on dams and rivers throughout the country.

Since Portugal has vast water resources, it could be suggested that pilot training and education (at an advanced stage) could take these resources into account, starting with using them for emergency landings. A study could also be carried out on the introduction of new water landing sites, with suitable infrastructure, to see if overall flight safety would improve in light-aircraft operations, across their various forms and applications.

When idealising these type of infrastructures and its location, a study of the site should be carried out to check its compatibility with the project to be developed. Some of the factors that are usually checked in other countries, among many others are: the maritime movements at the site, including currents and swell, the relationship between the depth of the bottom of the water mirror on the proposed water runway and the available length of the runway that is obstacle-free and safe in relation to the size and aircraft to be used [11]. Also, space to install typical infrastructure such as a hangar, a fuel tank, one or more floating docks, a ramp, one or more buoys, at least one assistance/rescue vessel and a small maintenance facility [12] should be provided for the creation of an amphibious aircraft base. Despite all this, pilots can only take advantage of these sites by having proper training since ditching is considered to be a dangerous manoeuvre for inexperienced flight crews [9].

According to the experts, there are lot of factors that should be considered when water landing. Among them: wind direction and speed, presence of swell and, if present, direction of their movement, the pilot's skills, training and experience. Additionally, the aircraft performance and characteristics should not be forgotten or underestimated [13]. Therefore, pilots must receive specific training not only to be able to take advantage of water landing sites, but also to correctly assess the risks in preparation for each mission.

1.2. Object and Objectives

The objects of this Master Dissertation are the design of new water landing infrastructures and water landing training guides for fixed-wing aircraft capable to operate at those sites.

This Master Dissertation has 2 objectives:

1. The design of water landing infrastructures at 2 Portuguese dams – These infrastructures need to comply with all the international standards and recommended practices for the design, operation, and maintenance of aerodromes present in the ICAO Annex 14 – Volume 1 (for fixed-wing aircraft) [14]. Each ICAO Annex addresses the materialisation of practices and recommendations for each topic related to civil aviation, with Annex 14 referring to aerodromes in general. Moreover, all of the parts that constitute the ICAO Document 9157 – Aerodrome Design Manual [15] should be considered as well. This document provides a detailed practical guidance for implementing the standards mentioned in the Annex 14 on the water landing infrastructures to be developed. By performing a brief analysis of ICAO Annex 14, it is possible to conclude that this document does not differentiate between land and water aerodromes when referring to the surface from which aircraft can land or take-off [16]. However, since the operations of aeroplanes in water differ significantly from those conducted on land, ICAO issued another guidance document, that becomes important to analyse in this Dissertation since it approaches the topics that are lacking in Annex 14 – Asia Pacific Regional Guidance on Requirements for the Design and Operations of Water Aerodromes for Seaplane Operations [16]. The specifications outlined in this document focus on the necessary facilities, services and equipment of water aerodromes.

   With regard to the certification of the proposed infrastructure, EASA Regulation 139/2014 [17] provides the necessary requirements for this purpose at aerodromes located in European Member States. Even so, since the proposed infrastructure will not exceed 10,000 passengers and 850 cargo movements per year[3], it will only have to comply with the Portuguese legislation described below. Nevertheless, it is important to analyse the Regulation in order to understand the European standard for aerodrome certification. Having said that, the proposed infrastructure must comply with the Portuguese Decree-Law 186/2007 of May 10th [18] (that was altered by the Portuguese Decree-Law 55/2010 of May 31st [19] and later on by the Portuguese Law 37/2023 of July 31st [20]). The national legislation mentioned have the aim to establish the conditions for construction, certification, and operation of national civil aerodromes and to set the operational, administrative, safety, and facilitation requirements to be applied to these infrastructures, and proceed with the operational classification of national civil aerodromes for airport planning purposes [18]. In order for this goal to be achieved, the results should be extrapolated to general guidance that can be used in other suitable, necessary locations.

2. The development of a new training guide for the water landing manoeuvre on fixed-wing aircraft – This guide will be firstly based on the EASA Easy Access Rules (EAR) for Aircrew document [21]. This document is a publication that provides a more comprehensive and practical interpretation of the Regulation (EU) No 1178/2011 [22] for aircrew members and aviation training organisations, for example [21]. Among other topics, this Regulation addresses the training and qualification standards for different categories of aircrew and the operational procedures and limitations for them. This training guide will also provide the guidance for a water landing risk assessment guide based on the Regulation (EU) No 965/2012 [23], on EASA AMC/GM to Part-NCO [24] and the stricter Part - NCC [25]. These documents are essential for ensuring compliance with European aviation regulations, providing clear guidance and acceptable means of compliance for safe and standardized air operations. The documentation produced in this Dissertation can also be used and applied by ATO as a guide for the training on the ditching manoeuvre as an emergency on.

[3] Information available at: European Union. (2018). *Regulation (EU) 2018/1139 of the European Parliament and of the Council of 4 July 2018 on common rules in the field of civil aviation and establishing a European Union Aviation Safety Agency*. Official Journal of the European Union – Chapter 1 – Article 2

1.3. Methodology

This Master Dissertation comprises three distinct phases:

The first one relates to better understand the current state of the art. At this phase, the researched Bibliography will be exposed. Reports published by GPIAAF that are related to ditching events will be analysed, especially their conclusions and recommendations. At this stage, the research of existing water landing sites will also be analysed. As such, not only the research into the legislation and regulations related to this aspect will be conducted but also contact with air operators or providers that have experience in the aquatic environment, in particular, in water landings, will take place. Some of these operators are contracted for rural firefighting operations through the coordination of the Autoridade Nacional de Emergência e Proteção Civil (ANEPC) [26] as a state resource for this purpose. By contacting them, it will also be possible to gather information on water landing sites that are being used as of today for water retrieving manoeuvres – *scooping*. Furthermore, the Autoridade Nacional da Aviação Civil (the Portuguese National Authority of Civil Aviation - ANAC), should also be contacted, to better understand which are the applicable legislations to this kind of infrastructures.

The second phase is based on the previous one. With the information gathered, the objectives proposed should start to be addressed. The evaluation of international, European and Portuguese requirements necessary to design and ensure the operation authorization and eventually grant the certification of these water landing locations. The same process will be applied to training content that comprises also the risk assessment material as well.

The third and last phase involver producing a proposal for two water landing infrastructures at two Portuguese dams. The decision to place each element in the infrastructure will be subjected of a critical and duly justified choice. Furthermore, regarding the second objective of this dissertation, the production of a procedural training guide to be used when using the proposed infrastructure will be based not only on the regulations analysed in the second phase, but also on documentation produced by other countries that face this reality on a daily basis and that have studied it, particularly Asian countries.

1.4. Dissertation Structure

This Master Dissertation comprises five distinct chapters:

Chapter 1 – Introduction – The presentation of a brief overview of the work to be developed throughout the whole project. This part will contain the Motivation, Object and Objectives, Methodology, Dissertation Structure and relevant Definitions.

Chapter 2 – Literature review - In this chapter, the literature review will take place. The analysis of past accident and incident reports regarding water landings produced by GPIAAF and equivalent organisations across the world will take place. Already existing water landing infrastructures and water landing procedures will be also analysed and discussed. Moreover, the relevant found literature regarding the design of water aerodromes will be presented, as well as the regulation adjacent to this aspect. Additionally, existing and already implemented training methods and risk assessment will be researched and exposed in this Chapter.

Chapter 3 – Regulations for Water Landing Infrastructures and Water Landing Training – The study of these regulations will provide the necessary information for the definition of the new requisites for building water landing sites compatible with European and Portuguese guides and legislation mentioned in the Object and Objectives subchapter. Additionally, the new training and risk assessment guides will be addressed in accordance with the active regulations mentioned as well.

Chapter 4 – Case Study - In this chapter, it will be carried out a study for the presence of existing water landing infrastructures in Portugal. According to that study, 2 locations will be chosen and their suitability for the project will be studied according to the criteria set in Chapter 3. As in previous chapters, the training material will also be subject to a suitability assessment.

Chapter 5 – Conclusions - The final conclusions of this Dissertation. It will include a brief Dissertation synthesis, final considerations and future perspectives related to the topics approached during this work.

1.5. Definitions

Aerodrome – A defined area on land or water (including any buildings, installations and equipment) intended to be used either wholly or in part for the arrival, departure and surface movement of aircraft (ICAO) [14].

Aerodrome Beacon – Aeronautical beacon used to indicate the location of an aerodrome from the air (ICAO) [14].

Aerodrome identification sign – A sign placed on an aerodrome to aid in identifying the aerodrome from the air (ICAO) [14].

Airside – Areas at an airport where aircraft and navigational aids can be found, such as runways, taxiways, aprons and hangars (FAA) (Adapted from [70]).

Ditching – Controlled emergency landing of an aircraft on water (Skybrary) [1].

Landside – Areas not accessible to aircraft. They are typically accessible to the general public and include areas such as roads, parking lots, unsecured portions of hangars and other buildings, and other public areas (FAA) (Adapted from [70]).

Landing Area – The part of a movement area intended for the landing or take-off of aircraft (ICAO) [14].

Manoeuvring Area – The part of an aerodrome to be used for the take-off, landing and taxiing of aircraft (ICAO) [14].

Marker – An object displayed above ground level in order to indicate an obstacle or delineate a boundary (ICAO) [14].

Mooring – A fixed permanent installation on the water surface used to secure seaplanes. The seaplane may be moored to a floating buoy, a pier, platforms, etc (ICAO) [16].

Runway – A defined rectangular area on land aerodrome prepared for the landing and take-off of aircraft (ICAO) [14].

Taxiway – A defined path on a land aerodrome established for the taxiing of aircraft and intended to provide access to aircraft stands only (ICAO) [14].

Turning Basin – A water area used for the water taxi manoeuvring of seaplanes along shoreline facilities and at the ends of a narrow water runway (ICAO) [16].

Weathervane – The tendency of the aircraft to turn into the relative wind (Shark Aviation) (Adapted from [60]).

2. Chapter 2 – Literature review

2.1. Chapter Introduction

ICAO was founded in 1944 when the Convention on International Civil Aviation (Chicago Convention) was signed. This UN organisation specializes in establishing international standards, recommended practices and procedures covering all aspects of International civil aviation operations. This organisation cooperates closely with its 193 state members to reach consensus on Practices and Policies to ensure a safer, more efficient and more economically and environmentally responsible aviation operation. The Convention resulted in a series of articles that materialize through 19 documents called ICAO Annexes. Portugal was one of the first 52 states to sign the Convention on December 7th, 1944.

According to the Article 26 of this Convention, each contracting state should undertake investigations of accidents and incidents that occur in its territory with the purpose of prevent similar accidents [27]. In order to carry out those investigations, ICAO issued the first edition of the Annex 13 – Aircraft and Incident Investigation in 1951 [28]. This document, which is now on the 12th edition (2020), provides standardized, specific guidelines and procedures to be approached by state members on those investigations. It is important to mention *that "The sole objective of the investigation of an accident or incident shall be the prevention of accidents and incidents. It is not the purpose of this activity to apportion blame or liability"* [28]. In this context, each state should constitute an AIA – Accident Investigation Authority - that operates within the vision of the documents issued by ICAO. This AIA should operate independently from the national aviation authority or any organisation, whose interests or duties may conflict with the mission entrusted to it or influence its objectivity. In Portugal, that organisation is Gabinete de Prevenção e Investigação de Acidentes com Aeronaves e de Acidentes Ferroviários (GPIAAF) [5].

By researching into previous water landing accidents, similar recommendations are revealed, emphasizing key aspects that can be implemented by both operators and authorities.[4] As such, the importance of addressing new Water Landing infrastructures and procedures available in other countries and other operators becomes evident.

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[4] The S. João da Caparica beach accident involving the Cessna C-152 (CS-AVA) in 2017, which resulted in 2 fatalities, was not adressed due to an ongoing court investigation at the time of this Dissertation's writing.

This research can provide a glimpse into what could be developed in Portugal and its significance on overall flight safety. This research could also be integrated into flight school training, to assist pilots in training for ditching manoeuvres. By incorporating this knowledge, pilots can better prepare for emergency situations involving ditching and enhance their ability to respond effectively.

2.2. Past Relevant Water Landing Accidents/Incidents in Portugal

2.2.1. Case 1: OH-YES – Alto Rabagão Dam – July 10th, 1997 [29]

The amphibian aircraft, Aerofab,Inc/Lake model 250, privately owned, has departed from Chaves Municipal Aerodrome (LPCH) with the aim of performing successive water landings and take-offs on the Alto Rabagão/Pisões Dam.

Figure 1 - Probable Route of the aircraft prior to the accident [29].

The Alto Rabagão/Pisões dam (dam chart with the aircraft's probable route presented on Figure 1) is an artificial lake created by a hydroelectric power station. The overall extension of the dam is around 10 km when it's at its full capacity. According to the organisation responsible for its utilization, they had no competence or any kind of authorization to allow the water landing of amphibian aircraft [29].

Figure 2 - Lake 250 Amphibian Aircraft [31].

The aircraft involved was a Lake 250 (general view on Figure 2), that is an American amphibian hulled, single-engine and single-pilot medium-wing aircraft with a semi-monocoque primary structure with metal cladding, with the exception of some secondary and non-structural fibreglass areas, retractable tricycle gear with hydraulic option and doors only on the forward gear, with the power unit installed on a mast above the fuselage, and a three-bladed variable pitch metal propeller [29], [30].

The pilots were fully licensed to fly (with the Pilot-Flying having only the Private Pilot License with less than 150 Flight Hours and the Pilot-Monitoring with the Commercial Pilot License), and all the approved Flight Manual procedures were conducted. In spite of this, at the final stage of water landing, the dynamic longitudinal stability of the aircraft was not achieved, for undetermined reasons, which led to the aircraft's roll [29].

According to the pilot's and witnesses' testimonies, the sky was clear with the absence of wind. The temperature was around the 20ºC. The surface of the water was calm, presenting a glassy surface. According to INAC (at the time GPIAAF did not exist and INAC accumulated both aeronautical authority and accident investigation authority functions), this situation is predicted in the Flight Manual of the aircraft by establishing an appropriate aircraft attitude for this manoeuvre [29].

The flight crew had the safety belt on, in accordance with what the Flight Manual stipulates. They do not have any recollection on how they were able to unfasten them. In spite of this, according to the manufacturer's flight manual, the occupant survival in an event of ditching is unpredictable due to all the different combinations of scenarios that can cause it [29].

The aircraft technical documentation was lost because it was inside the aircraft when it sank. As such, the investigators had to recur to the pilots and their knowledge of the aircraft maintenance/anomalies history. The pilots stated that the aircraft had no pending issues and that nothing was noted during the pre-flight inspection. In spite of this, when the last water landing was taking place, the pilots noticed a loss in hydraulic pressure, forcing them to manually actuate the hydraulic pump to restore the pressure on the hydraulic circuit. The insufficient hydraulic pressure can cause the trim malfunction, resulting in an inappropriate aircraft attitude at the moment of contact with the water [29].

Due to the nature of the accident, the investigation authorities did not issue any recommendations [29].

2.2.2. Case 2: RF-21512 – Aguieira Dam – July 6th, 2006 [32]

The Russian amphibian aircraft, Beriev BE 200-ES departed from Monte Real Air Force Base (BA5) to perform a firefighting training mission on the Aguieira Dam. In order to do so, the flight crew should perform scooping manoeuvres, not only on the Aguieira Dam, but on the Castelo de Bode Dam as well (the dam chart is presented in Figure 3). This aircraft was in a trial experience, with the aim of future acquisition, to help in the firefighting efforts.

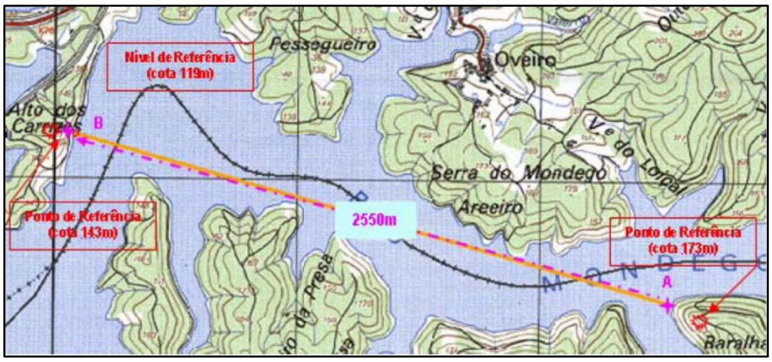

Figure 3 - Aguieira Dam Chart [32].

The Aguieira Dam is located in the Mondego River, and it has several streams that merge into the dam. The available distance for the scooping manoeuvre, according to the Portuguese Army charts as in Figure 3, was around 2550 metres [32].

Figure 4 - Beriev BE-200 ES Reg. RF-21512 [33].

The aircraft involved in this occurrence is the Beriev BE-200 ES that is a multi-pilot, multipurposed amphibian hulled, high-wing aircraft, equipped with 2 turbofan engines and tricycle landing gear. This aircraft has a pressurized cabin [32], [34]. The specific aircraft involved in this incident is presented on Figure 4.

The investigation determined that the flight crew was fully licensed (with both Pilots having a Test Pilot License with the Captain having around 4300 Flight Hours and the First Officer with around 6700 Flight Hours of experience) for that kind of operation and that the aircraft was fully airworthy, according to its technical documentation [32].

On the 3rd scooping manoeuvre, within the planned flight trajectory illustrated on Figure 8, the aircraft was supposed to scoop 6000 litres of water. According to the flight crew, the approach was taken with full flaps and slats, at around 200 km/h. The aircraft touched the water with the lowered scoops at around 190 km/h, however, the speed declined to 160 km/h. As such, the pilots retracted the scoops to reduce drag and increase the speed to 180 km/h, at which point the scoops were lowered again. After the retrieval of 6200 litres of water, the scoops were finally retracted, and the aircraft accelerated to the take-off speed [32].

In spite of the efforts done by the pilots to take-off, it became clear to them that they were not capable of surpassing the obstacles – some 10/15 m tall eucalyptus on the margin – eventually hitting them with both wings. The engines ingested branches, leading to the overheating of the left engine, which the pilots cut off. The remaining engine was set to full power and the water on the tanks was dumped. The aircraft returned to the military base with one engine operating and landed with no further incidents [32].

Through the aircraft performance analysis, and by comparison with general guidance for scooping, GPIAAF determined that in order for the retrieval of 6200 litres of water, the aircraft would need around 2800 metres of water strip, a value that is higher to what was available. As such, distance available for the last scooping exercise was insufficient, resulting in damage to the aircraft. It was also noted a flight crew deficient CRM. There were no other recorder damages, other than on the aircraft and on the trees that it hit [32].

The cause of this incident was attributed to an error on the determination of the geographical coordinates of the start and end of the water sectors intended for the scooping operation. This error led to an overestimated water strip length for the retrieval of that amount of water. GPIAAF stated that the one of the factors that contributed the most for this incident was the lack of precision on the determination of the available scooping distances. If these calculations are important for light firefighting aircraft, it becomes more important on large aircraft such as the Beriev and similar counterparts. As such, the investigation authority recommended that the entity that overrules the firefighting operations – at the time called Serviço Nacional de Bombeiros e Proteção Civil – proceeds to a more appropriate evaluation of the available dams and their feasibility to this operation [32].

Moreover, they recommended that entity to perform distance calculations on the areas susceptible to this kind of operation, as well as identify surface or submerged obstacles that can compromise aircrafts in mission. Additionally, this content should be spread across firefighting operators [32].

2.2.3. Case 3: EC-JLB – Roxo Dam – July 19th, 2012 [35]

The Spanish registered Air Tractor Fireboss aircraft was performing a firefighting mission in Tavira, Algarve with a group of four similar aircraft. This group departed from their base at Proença-a-Nova Aerodrome (LPPN) and discharged a water load on the fire. Before proceeding to water scoop at the Roxo dam, the aircraft needed to refuel at Beja Air Force Base (BA11).

Roxo Dam is located near Beja, and at the time of the accident (with the accident trajectory depicted on Figure 5.), it counted with a relatively high-water level. Another positive aspect of this dam, regarding water scooping operations, is the absence of obstacles on its margins as well as no electric power lines in the zone. Additionally, its relative long length is also an advantage, by allowing the drawing of a virtual runway well above the needs for this operation [35].

Figure 5 – EC-JLB Aircraft accident diagram [35].

The Air Tractor Fireboss AT-802A is a single-pilot, single-engine, low wing amphibian aircraft that possess floats to operate in water and a retractable landing gear to operate on land, making it a versatile aircraft. This aircraft is used for agricultural purposes as well as firefighting operations, among others. This aircraft is equipped with a water scooping system that allows the water to refuel at a rate of around 3100 litres per 30 seconds [35], [36]. Figure 6 presents a photography of this aircraft.

Figure 6 - Air Tractor Fireboss Aircraft [35].

The 63-year-old pilot was fully licenced to fly the aircraft and to perform this type of mission. By having almost 10000 flight hours, the pilot was considered to be experienced and proficient [35].

The four aircrafts were divided into two groups, with the EC-JLB one being the 4th aircraft overall, on the far-left side of the formation. This is done to avoid surface waves created by preceding aircraft, using the virtual water runway, starting from the right-hand side [35].

After the water scoop has been completed, the aircraft set full power to take-off. However, in spite of being in formation, it lost control due to the wake turbulence caused by the other aircraft (refer to Figure 7 for illustrative reference). After losing control, the pilot actuated the emergency water discharge lever and by the time when the control was recovered, the aircraft was heading 45º to the left of the intended one. Due to this fact, the aircraft floats hit the water, and the left one separated from it. After this, the aircraft hit the margin twice, causing the remaining float to break (after which remained afloat) and the aircraft sank a few metres ahead, in a very sudden manner. This way, the aircraft became permanently damaged, which could justify not to be repaired [35].

The pilot of the aircraft could survive the accident by evacuating the Air Tractor quickly

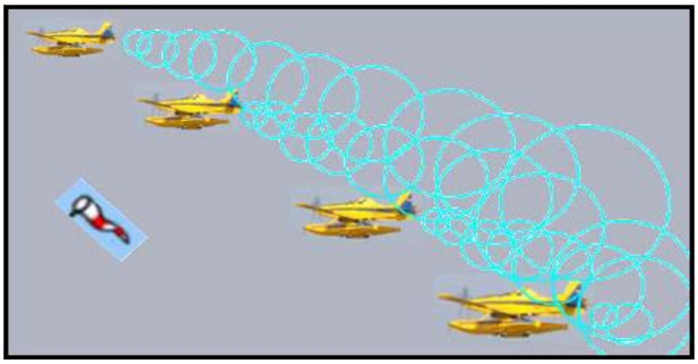

Figure 7 - Air Tractor Wake Turbulence diagram [35].

and by swimming to the shore with the aid of a floating vest. He was secured to the aircraft by a five-point seatbelt and was equipped with a helmet. Later on, he was rescued by a Portuguese Air Force helicopter and transported to BA11. Afterwards, and since the pilot has not shown any kind of worrying symptoms, it was sent home [35].

At the time of the accident, the aircraft was fully airworthy, as proven by the technical documentation and certificates issued by the Spanish Civil Aviation Authority. According to the operator's maintenance organisation, there were no anomalies pending or any kind of reports of malfunction. Furthermore, the organisation had a fully approved

Company Operations Manual by the Spanish Civil Aviation Authority – Agencia Estatal de Seguridad Aérea (AESA) [35].

In regard to the weather, it was clear sky, with light to moderate North-westerly wind, high air temperature, capable of reaching 39ºC [35].

The investigation concluded that the *"primary cause of the accident was the temporary loss of control of the aircraft, by the pilot, causing a lateral deviation toward the left margin of the lake, reducing available distance for take-off before the margin being impacted by aircraft floats"* [34:18]. In addition to this aspect, it was verified an insufficient manoeuvre planning, without considering the lateral wind influence on wake turbulence. This blowing-from-the-right lateral wind, on a line to the left configuration, causes the wake turbulence to move to the left, influencing more and more the aircraft that are further behind in the formation. The increased wake turbulence affected the control surfaces of the last aircraft, causing it to lose control and making it turn left [35].

Since, at the time, GPIAA considered the primary factor that contributed to the accident was the presence of wake turbulence, the organisation recommended that a more thorough operation planning should take place, with an alternative type of formation to be chosen. This new formation should take into account the effects of wind on aircraft performance and control in order to not affect them during scooping manoeuvres [35].

2.2.4. Case 4: CS-AHQ – Trafaria, Almada – August 30th, 2015 [36]

The aircraft Cessna FR172H (depicted on Figure 8) departed from Cascais Airport (LPCS) in Lisbon, for a banner towing mission. The primary mission consisted of fly over Guincho and follow the shoreline to Caxias, with the subsequent crossing of the Tagus River to Fonte da Telha and return to Cascais (LPCS). This was the aircraft's second flight of the day with a flight crew of two. The secondary mission of this flight was the training and associated rating to the right seated pilot [36]. This case is not related to manoeuvres regarding water landings, but it has comprised a ditching emergency manoeuvre, and as such, it becomes important to address it.

It is important to note that in spite of this accident have occurred in 2015, the GPIAAF report was only issued in 2022.

Figure 8 - Cessna FR172H CS-AHQ [37].

The Cessna FR172H Reims Rocket is a terrestrial French version of the single-pilot 172L, 4-seater light aircraft with fixed tricycle landing gear. This aircraft has a more powerful engine than its counterpart as well as a variable pitch propeller. The aircraft technical documentation provided showed that the aircraft was fully airworthy in spite of the vibrations felt by previous flight crews [36].

The left seated pilot was fully qualified to perform the flight with around 4100 flight Hours of experience and with the nuance of banner towing certification. The remaining pilot had a valid license as well, but in this case only with around 220 Flight hours of experience. In spite of this, this pilot was performing a towing rating on the flight [36].

After 35 minutes had passed since the start of the mission, when the aircraft was starting to cross the river, it started to make abnormal noises accompanied by signals of power loss. After this acknowledgement by the pilots, they started troubleshooting procedures to solve the anomaly. At this time, the aircraft was flying at 600 feet of altitude. Without success, the flight crew made the decision to drop the banner over the river left shore to reduce drag and maintain flight with the current engine limitations. After this, the pilot turned left with the aim to land on the beach near the Trafaria silos [36].

After a loud, sudden noise, the engine stopped, and the previous landing strategy had to be revised. As such, the plan now was to land in the nearest beach. To do so, the pilot configured the aircraft with full flaps to reduce groundspeed, as much as possible. In spite of this, since there was a strong tail wind component they couldn't land on that beach and the pilots turned left to try to land on that beach in the opposite direction, with a headwind component. On the turn, the aircraft lost too much altitude turning the landing on the beach impossible. As such, the pilot decided to level the aircraft wings, hold the nose up and ditch the aircraft on the river [36]. The estimated trajectory is presented on Figure 9.

Figure 9 - Estimated trajectory and resting position of the aircraft [36].

For some time, the aircraft remained afloat, allowing the pilots to evacuate the aircraft by their own means. It's important to note that the right seated pilot was able to escape the aircraft during the last stages of the flight while the left seated pilot remained on the aircraft because it wasn't able to open the door. The pilot outside the aircraft broke the back window and helped the other pilot to escape. Eventually the aircraft sank and rested on the riverbed at around 25 metres of depth. Both pilots were rescued by local fisherman and transported to a hospital due to minor injuries [36].

The technical analysis of the remains of the aircraft's engine determined that the case was broken near the cylinder #2. This was due to the breakage of the crankshaft and consequently the connecting rod came in contact with the case wall, breaking it. It's important to note that it was verified that the operator's maintenance services had removed the propeller spinner due to vibration, some days before the accident. Regarding safety equipment, such as life vests, it was not present on the aircraft and as such, the pilots could not rely on them. The safety belts helped during the rapid deceleration on impact but prevent the left seated pilot to evacuate easily [36].

According to the Commission Regulation (EU) No 965/2012 of 5 October 2012, that also regulates the banner towing commercial activity under the Annex VIII – Part SPO, it is stated that: *"Before commencing a specialised operation, the operator shall conduct a risk assessment, assessing the complexity of the activity to determine the hazards and associated risks inherent in the operation and establish mitigating measures"* [23:11]. Additionally, under the SPO.IDE.A.195 flight over water requirement: *"single-engine aeroplanes shall be equipped with a life-jacket for each person on board, that shall be worn or stowed in a position that is readily accessible from the seat or station of the person for whose use it"* [38]. It was determined by GPIAAF that the operator wasn't aware of the risk in its operating procedures.

This investigation concluded that the probable root cause for the accident was the crankshaft failure, caused by the continued degradation over the time of the engine centrifugal pendulum vibration absorption system. This degradation was due to the non-compliant inspection processes during the engine last overhaul, according to the applicable maintenance instructions. The lack of technical assessment of the vibration by the operator's maintenance service provider and its decision to keep the engine in service contributed to the degradation of the components as well [36].

Since the operator took action in regard to additional mitigation measures on its risk assessment, GPIAAF did not issue formal recommendations on this report. The actions taken by the operators were the following [36:14]:

1. *"Conduct a carefully pre-flight inspection, performing the fuel drains, with special attention to fuel tanks water condensation;*
2. *Engine run-up in accordance with the checklist;*
3. *During the flight monitor all the engines' instruments;*
4. *In case of ditching try to perform it near a boat and away from land;*
5. *Always wear Safety Vest;*
6. *Implement ditching manoeuvres in the training program;*
7. *Keep a safe distance from land".*

In spite of this, GPIAAF advised operators to maintain contact with maintenance organisations when reports of abnormal vibrations are felt. This way is promoted a information exchange that allows a sustained technical assessment and mitigation measures. It is also advised that maintenance shops follow the manuals and inform the organisation of any lack of supplies or experience for specific maintenance tasks. The problems shall not be ignored due to this fact. Additionally, through the publication of the report and the recommendations on it, GPIAAF advises pilots to always report operational issues on the aircraft to reduce the life-threatening exposure that the operation may present [36].

To conclude, it is advised that the aeronautical community impacted by this investigation in regard to its operation resemblance to take the necessary actions mentioned in the report.

2.2.5. Case 5: EC-JUB – Castelo de Bode Dam – July 3rd, 2019 [39]

A pair of Air Tractor Fireboss aircraft (denominated A7 and A8) departed from Proença-a-Nova (LPPN) aerodrome during a fire event near Pombal. Both aircraft were supposed to fill up with water at the Castelo de Bode dam and return to discharge at the fire location.

The aircraft, Air Tractor AT-802AF, presents a similar configuration to the one mentioned in the 2.2.3 - Case 3: EC-JLB – Roxo Dam – July 19th, 2012 [35] subchapter.

The pilot of the A8 aircraft was fully licensed to carry out this kind of operation, having significant flight hours in this aircraft, with around 4300 of total Flight Hours and around 1200 Flight Hours of experience on this type of aircraft [39].

After take-off, both aircraft were contacted by CMA that requested the take-off time. This is an operator standard to verify the status of the landing gear of both planes reciprocally. As such, after the communication with the CMA, the A7 aircraft responds to the A8 stating that the landing gear is *"in transit"*. Both aircraft started to pursue the fire heading, positively identifying the fire location and the A8 aircraft inserted its coordinates on the GPS. After this, both aircraft maintained contact with each other on one of the available radios, while alternating the frequencies on the other radio in order to communicate the flight progress with both fire-fighting frequency (CNOS) and the flight information service, Lisbon Mil. Additionally, both aircraft should remain in contact with AFIS services at the same time with the CNOS [39].

After confirming the water landing location in the Castelo de Bode dam, the pilots stated that there were power lines in the approach. The pilots then checked the wind and made a low pass on the dam (S-N direction) with tail wind component present. After this, they made a left turn to perform the scooping manoeuvre (N-S direction). On the final moments that preceded the water landing, the A8 pilot states that he had verified the configuration of the aircraft, taking also into account the propeller pitch, flaps, referring "four blue" for landing gear position, as well. This aircraft counts with eight position-indicator lights, four of which are blue and related to the gear UP condition and the remaining four are green and related to the gear DOWN condition [39]. These indication lights are depicted in Figure 10.

Figure 10 - Fireboss Landing Gear control panel [39].

The A8 aircraft pilot, at the moment of contact with the water, felt an immense impact due to the strong deceleration of the aircraft. This situation was immediately reported to the flight information service by the other aircraft; however, the message was not transmitted successfully. The impact forces were enough to activate the ELT emergency locator transmitter. The pilot was able to evacuate the aircraft after removing some loose items and swims to the shore while the aircraft sank. The event was reported by the pilot, who was both able to leave the occurrence unharmed and have time to alert the authorities. As consequence of the latter fact, the SAR services were not activated [39]. The approximated final flight path of this occurrence is depicted below, on Figure 11.

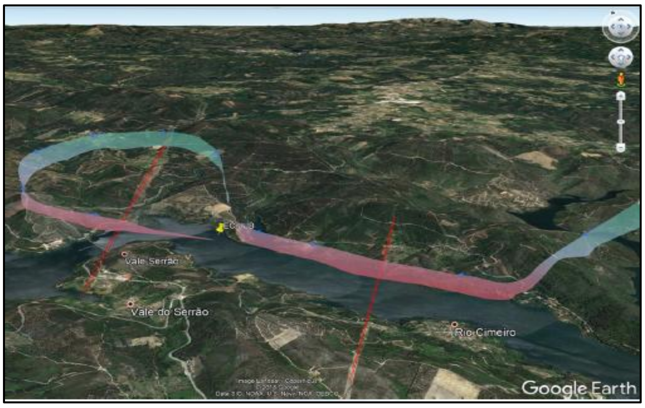

Figure 11 - Aircraft approximated final flight path [39].

The aircraft sustained substantial damage on the engine, propeller, wings and airframe. Additionally, the floats separated from the aircraft as well.

The investigation concluded that the most probable cause for this accident was the extended position of the landing gear, suitable for ground landing only. If the landing gear is found in this position during the water landing, the front wheels act as a pivot point (refer to Figure 12 for visual reference), making the aircraft rotate around its lateral axis. In spite of this, the aircraft did not roll, having returned to its horizontal position [39].

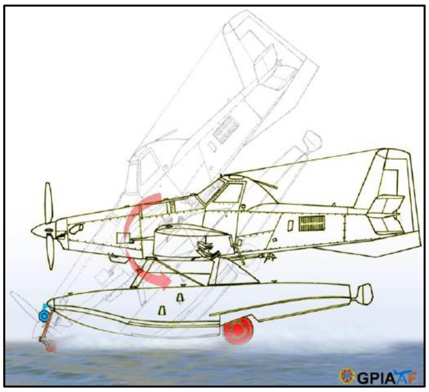

Figure 12 - Landing gear down water landing dynamics [39].

The failure to retract the landing gear was probably motivated through the interruption of established procedures after take-off because of mission communication with CMA. The aggravated workload during the flight did not allow the pilots full concentration on the critical tasks necessary to perform this kind of operation. As such, it was verified that the basic flight priorities between *"aviate – navigate - communicate"* were not followed due to the workflow overload of the operation. Additionally, it was verified that the procedures put in place to prevent this kind of situation were not effective [39].

GPIAAF stated that this kind of operation is extremely complex and heavy work loaded. Furthermore, as the aircraft is extensively configurable to different kind of operations, should enforce the pilots to take a more careful, sequenced management of its configuration. The single-pilot operation constitutes another hazard that, in spite of being reduced by training and through a follow-up of procedures, are not totally mitigated but still accepted by certification authorities as a restricted category only by the type of mission performed. Moreover, it was concluded that when the pilot indicated the state of "four blue" for the landing gear configuration, given the workload and the inherent distraction, and with the addition of the English not being his native language, the pilot may not have correctly associated it with the actual colour. It was also found that the English aeronautical language is not effective in communications with the flight information service.

For this case, GPIAAF did not issue safety recommendations, however it highlighted some improvement aspects for the operator, Agro-Montiar. Those were the following [39:10]:

1. *"All pilots in firefighting operation within national territory will have an aeronautical English ICAO level IV. In addition, the operator initiates a campaign to promote standard phraseology with a special emphasis on VFR[5] operation.*
2. *The current crosscheck landing gear confirmation procedure will be reviewed, mentioning and specifying standard phraseology and the aircraft relative position for the intended landing gear position crosscheck.*
3. *The "Sterile Cockpit" concept and procedure will be implemented, including the flight phases definition where external inputs will not be allowed to the normal conduct of the flight.*

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[5] VFR (Visual Flight Rules): *"Regulations for operating aircraft in Visual Meteorological Conditions (VMC), allowing flight by visual reference."* – Retrieved from FAA Airplane Flying Handbook (FAA-H-8083-3A).

4. *The accidented aircraft pilot attended an approved refresh flight training simulator held in Paterna, Valencia with briefings and analysis of similar situations to those present on the accident.*
5. *ANEPC will revise its INSTROP 01 2015 and/or other operational instruction documents so that the CMAs are sensitized to the delimited use of the mission radio frequency, that will be prioritized by aircraft crews".*

2.3. Conclusions of Past Water Landing Accidents/Incidents in Portugal

In this subchapter, the heavy workload and numerous variable factors that water landing related operations/emergencies impose is clearly evidenced throughout GPIAAF conclusions.

On Case 1, there were no safety recommendations due to the hydraulic failure of the aircraft, however, this case reinforces the need of a proper pre-flight assessment in ensuring that the aircraft is in proper conditions for the flight. Even so, it is also indirectly implied that a proper water surface contact of the aircraft is an important for this kind of mission.

Regarding the errors on the determination of the proper geographical coordinates of the water sectors intended for the scooping manoeuvre on Case 2, the importance of correct calculations of the distances involved, prior to the mission, are evidenced.

On Case 3, the thorough operation planning regarding wind effects on aircraft prior to the mission was emphasized. Due to all the complexities involved in aircraft formations and their impact on their performance, pilots shall consider these intricacies during low-level flights, in order to avoid accidents.

On Case 4, since the primary cause for this accident was mechanical failure, the recommendations are issued mainly in this regard. As such, these underline once more the importance of careful aircraft pre-flight inspections and a constant aircraft monitoring during flight. Furthermore, the importance of having the aircraft equipped with proper, accessible emergency life-saving equipment such as safety vests is highlighted. As these can only be effective with the correct ditching manoeuvres, training in this regard is pivotal. In this case, the reporting culture of anomalies is also encouraged as well as the diffusion of recommendations amongst operators.

Regarding the last case presented, even though GPIAFF did not issue any safety recommendations, the importance of maintaining focus on the mission, even in the most complex ones. This can be achieved through a “sterile cockpit” concept, by minimizing external interferences. It was also highlighted the importance of English communication training, in order to prevent misunderstandings during the mission.

The cases in this chapter emphasize the need for proper infrastructure, rigorous training, and meticulous planning to ensure safety in both emergency and routine operations. This includes, but it is not restricted to pre-flight checks, mission planning, and clear communication. One possible approach for the problem is to search for existing locations/operators that have this kind of infrastructure/training and relate the research to the Portuguese reality, while considering the relevant regulations, to ensure safe and compliant operations.

2.4. Water Airports/Aerodromes and Infrastructure

Amphibian aircraft can be a valuable asset for practical and recreational purposes. In addition to this, they can be used in special flight activities, such as firefighting, evacuation of people and delivering food or medical supplies. The ability of taking-off or landing in water, makes them extremely versatile, allowing their operation on remote areas or even in regions that lack proper airport infrastructure. In locations where water aerodromes are available, this kind of aircraft can both combine the advantages of an aircraft, such as speed, with the ones related to boats, such as accessibility [40].

According to ICAO, an Aerodrome is *“a defined area on land or water (including any buildings, installations and equipment) intended to be used either wholly or in part for the arrival, departure and surface movement of aircraft”* [14:1-2]. This definition, however, only refers to aerodromes in general, regardless of the type of surface for landing and ground manoeuvres. Since the operations to be carried out in land or water airports differ significantly, it becomes important to set different standards regarding water aerodromes certification. As such, on water aerodromes, a different approach on necessary facilities, services and equipment should take place [16].

The Asia Pacific Regional Guidance on Requirements for the Design and Operations of Water Aerodromes for Seaplane Operations defines Water Aerodrome as *“A defined area, primarily on water, intended to be used either wholly or in part for the arrival, departure and movement of seaplanes, and any building and equipment on ground or water”* [16:1].

There are many examples of water aerodromes around the world, as such, by comprehending how other countries develop this kind of infrastructures, a general idea of what needs to be built can be perceived. Additionally, since some of them were established a long time ago, their expertise on the matter is fundamental to ensure that their bases are the safest as they can be.

2.4.1. Lake Hood Seaplane Base (LHD), Alaska, USA

2.4.1.1. General Context

With around 1518800 km2 of land area, Alaska is by far the largest USA State [41]. In spite of this, it counts with a very limited road infrastructure [42]. For this reason, the population of remote communities rely heavily on Seaplane operations for their needs.

Lake Hood, located in Anchorage, serves as a Seaplane Base, and is the world's largest infrastructure of this kind [42]. This base started to be built in the late 1930's with the addition of a gravel runway and a canal that connected both Hood and Spenard lakes. Figure 13 presents an aerial view of the base in 1959.

Figure 13 - 1959 aerial image of Lake Hood, Anchorage, Alaska [43].

The gravel runway later became the Ted Stevens Anchorage International Airport (ANC). With the development of aviation activity in the subsequent decades, the base expanded with the addition of an air traffic control tower and additional tie downs. Later on, not only the five channel tiedowns/fingers, but the secondary channel – separated from the main one through the soon to be called Gull Island - to improve taxiway safety were constructed. In the 70's, the original tower was decommissioned and the ATC control moved to the ANC airport tower, becoming part of the operations of the airport.

Until today, the base made considerable improvements that can be perceived on Figure 14. Some notorious examples are the expansion and upgrade of existing facilities, a new water well to control the lake water level, paved gravel surfaces and constructed new aircraft parking spaces [44].

Figure 14 - Current aerial image of LHD [45].

2.4.1.2. Airside Facilities

The Lake Hood Seaplane base is equipped with a gravel runway – Runway 14-32 - that has four exits. These exits lead to a network of taxiways that can be used both by land vehicles and amphibian aircraft. Some of the taxiways include sidewalks for pedestrians. According to the Ted Stevens Airport Operations Manual [46], the aircraft have the right of way on shared use road surfaces and, in order to reduce the collision risk, is mandatory for the aircraft to taxi with the available external lighting, such as anti-collision lights for example.

Additionally, the base counts with three waterways, with different lengths and directions (presented in Table 1 and Figure 15), with large areas for manoeuvring at each end. During winter operations, when the conditions are favourable – ice depth of the frozen lake and no overflow risk– the waterways also serve as ski strips for aircraft equipped with skis.

Table 1 – LHD Runway/Waterway Characteristics [44].

Runway/ Waterway Orientation	Dimensions [m]	Surface Type	Runway Markings	Runway Lighting	Depth Range [m]
14-32	670.56 x 22.86	Gravel/Dirt	None	Threshold/MIRL	N/A
E-W	1384.10 x 57.30	Water/Ice	None	Channel (Partial)/MIRL	1,83 - 7,01
N-S	588.26 x 60.96	Water/Ice	None	None	1,83 -6,4
NW-SE	417.27 x 45.72	Water/Ice	None	None	2,44 - 6,4

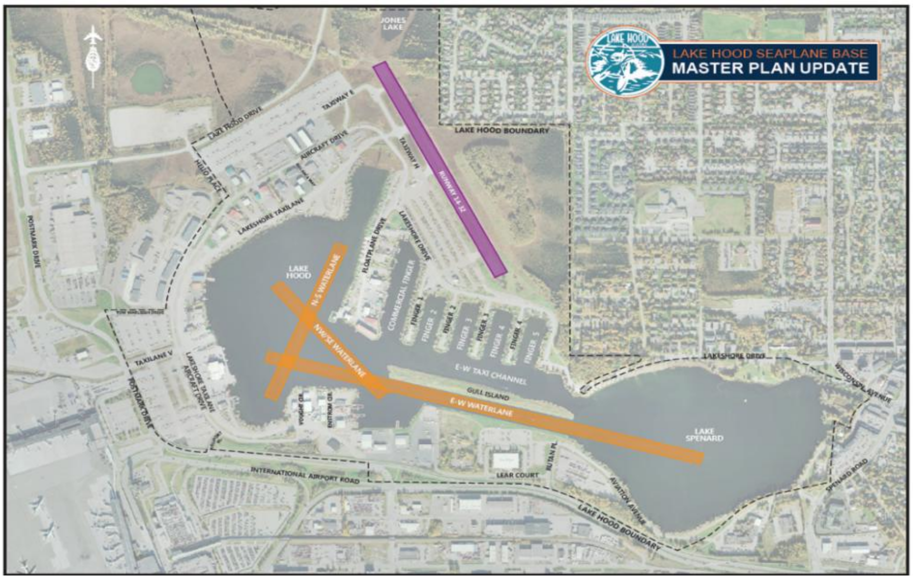

Figure 15 - LHD Runways and Waterlanes [44].

To support the waterways, the base is equipped with 2 public ramps (North and East Ramps) to assist the aircraft storage in multiple hangars located on the shore. Furthermore, there is also another ramp located on the south side, owned by the Department of the Interior - Aviation Management Directorate (DOI AMD). This ramp can be used, with permission, by larger aircraft during strong crosswind conditions or when the lake water elevation is low [44]. Additionally, the slow taxi water channel and the five fingers mentioned are still in use, with the first finger being dedicated for commercial purposes. These support infrastructures are illustrated on Figure 16.

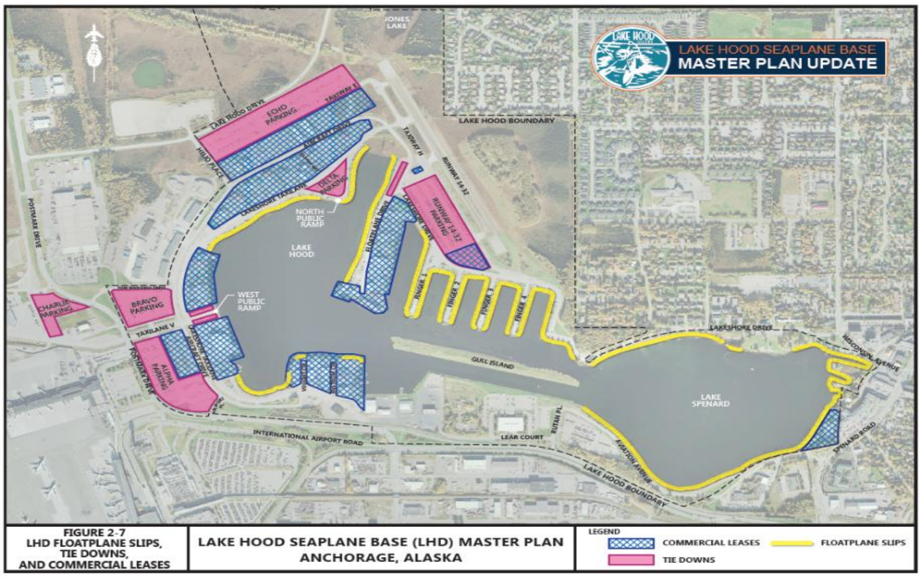

Figure 16 - LHD Floatplane slips, Tie Downs and Commercial Leases [44].

The land taxiways allow the aircraft to park on the five available parking aprons, from Alpha to Echo. On these locations, the owners can find gravel tie downs to secure the aircraft. The taxi channel, parallel to the E-W runway, allows the aircraft mooring on the docks available at the five fingers. The Gull Island also prevents wakes from taxiing aircraft to negatively impact the ones that are taking-off, landing or in taxi operations. The network of taxiways, roads and pedestrian routes is visually depicted in Figure 17.

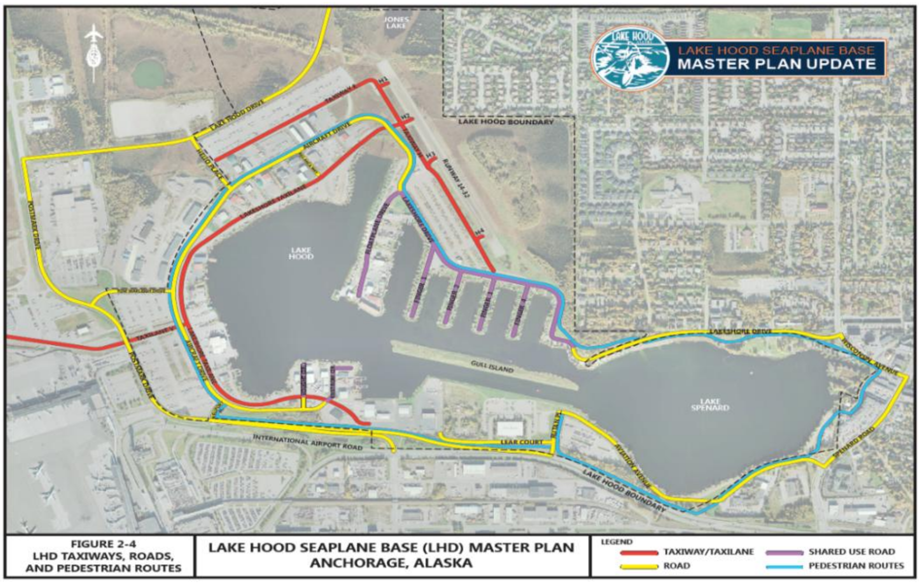

Figure 17 - LHD Taxiways, roads and pedestrian routes [44].

Concerning Airspace, the LHD seaplane base is classified as Class D airspace located within and below the ANC one. Class D airspace extends from the surface to 2500 ft AGL and up to 5 nautical miles from the airport's centre, including any instrument approach procedures associated with the airport. The airspace is then controlled and managed by local ATC Towers, which also provide guidance for ground operations. The aircraft is required to maintain communication with the ATC Tower. In spite of this, no separation services – procedures and measures implemented to ensure safe distances between aircraft in the airspace – are provided to VFR aircraft.

The LHD Seaplane Base is serviced by an ATC Tower, by an ARTCC, a TRACON and a FSS. The first three, when working as a group, provide safe separation between aircraft to IFR[6] or VFR flights. The last one, aids lost aircraft as well as emergency services, pilot briefings, flight clearance relays and weather and navigational aid status information. The majority of flights that operate in Lake Hood are under VFR, however, if pilots want to fly to the base under IMC conditions, they must do so under an IFR flight plan into ANC. Then, pilots are given the option to cancel the IFR approach into ANC if VMC exists and navigate under VFR into Lake Hood. If not, pilots must land on ANC under IFR and taxi to Lake Hood afterwards. These special procedures are in place due to the proximity

[6] Instrument Flight Rules (IFR): *"Rules that govern the procedure for conducting flight in weather conditions below VFR weather minimums."*- Retrieved from FAA Airplane Flying Handbook (FAA-H-8083-3A).

of LHD and ANC, preventing a stand-alone IFR procedure for Lake Hood. There is no standard visual navaid or approach slope guidance at LHD [44].

2.4.1.3. Landside facilities

The Lake Hood Seaplane Base counts with many different Landside Facilities. There are approximately 50 active commercial leases. Some notorious examples include the Echo Parking Lease and the Lake Hood Strip Lease. On the contrary, there are also non-commercial users, such as the Alaska Airman Association or the Alaska Aviation Heritage Museum, to name a few.

Even though there are no full-service fixed base operator, some private businesses provide services to the Seaplane Base users. Some examples are: hangar parking, 829 tie downs, 344 seaplane slips, 100LL Aviation Fuel sale and distribution, flight training, aircraft charter, maintenance, sales and rentals. Other non-aviation services are also provided, such as car rentals and car parking, hotels, shops, pedestrian recreation areas and public and sewer services [44].

To ensure safety levels in case of an emergency, the Ted Stevens International Airport Police and Fire is activated when an occurrence takes place. This is a team composed of around 60 people and serves both ANC and LHD. They conduct law enforcement, emergency, medical and aircraft rescue and firefighting operations. The security of Lake Hood is guaranteed by fencing, gates and signs that discourage unauthorised access. Additionally, airport police and management staff conduct periodic patrols of the property. Closed-Circuit Television cameras were also added to aid the security efforts [44].

2.4.1.4. Environmental Conditions

Regarding meteorological conditions, the Anchorage area climate is considered transitional between maritime and continental climate zones. Annually it counts with approximately 42.2 centimetres of annual precipitation, primarily as rain, and around 188 centimetres of snowfall. The summer temperatures vary around 11 to 18 Celsius degrees, while the winter ones vary from approximately -12 to -5 Celsius degrees. Since cloudiness conditions have little impact on operations at LHD, VFR operations prevail. The peak of cloud cover is usually registered in December. Prevailing winds are generally mild, averaging below 21 kilometres per hour annually, with a prevailing northward direction at 21% of the time. There are volcanoes in the 160-kilometre vicinity area, but the ashfall is an infrequent hazard to LHD [44].

When it relates to air quality, since 1996 no violations of the standard values of air quality set by the United States Environmental Protection Agency have occurred. Regarding water quality, the base has shown improvement over the last decade due to mitigation efforts, including reduction of glycol-containing runoff and drainage improvements, resulting eventually in compliance with criteria set by EPA.

FAA provides guidelines for the maximum allowed noise level since residential areas adjacent to the airports are directly affected by it. ANC, over the last years, has implemented noise abatement measures and improved land use compatibility in the vicinity of ANC and LHD. Two of the applied measures were the acquisition of residential land, residential sound insulation program.

The areas surrounding the Seaplane Base provide habitat for a large variety of wildlife and birds. Since they are considered a hazard to aviation, namely birds, the base has developed a Wildlife Management Program in response to the hazard of wildlife collision with aircraft. The vegetation present in the outskirts of LHD currently faces no risk of collision with the aircraft. However, another issue faced by LHD is the aquatic vegetation since it grows excessively on the lake, impacting the aircraft operations. In 2005, an Aquatic Vegetation management Plan was developed. This plan states that the ANC management is responsible for the excessive vegetation in the open waters of the lake, while the vegetation of the slips needs to be managed by their owners [44].

2.4.2.Lake Como Seaplane Base (LILY), Lombardia, Italy

2.4.2.1. General Context

Lake Como is a 47 kilometres long Y-shaped lake in the Lombardy region, northern Italy. It is located against the foothills of the Alps. This lake receives the Adda River and has a maximum depth of 414 metres [47].

This base saw its start of operations around 1913, with the first *Gran Premio dei Laghi*, a worldwide seaplane race. A few years after, in 1930, the Lake Como Seaplane base was established with the construction of a hangar the Aero Club Como offering seaplane rides and instruction. This fact means that it is the oldest seaplane operation in the world [48]. Many of the pilots trained in this location, ended up eventually at service of many Air Forces, with some of them dying in World War II. Figure 18 presents the Aero Club Como ramp back in 1930.

Figure 18 - Aero Club Como Ramp in 1930 [49].

Currently, the seaplane base is administrated by the Aero Club Como and is currently both the largest and the only one that is certified in Europe [50]. This organisation has a large fleet, composed also by historic seaplanes, all of them airworthy. They employ their airplanes for sightseeing experiences, training, film productions and activities like concerts are sometimes held in their facilities. They also help the Lombardy region civil protection by monitoring forest fires, water pollution and in search and rescue operations. The club also provides in their hangar (refer to Figure 19 for an aerial view), a maintenance facility.

Figure 19 - Aerial view of Aero Club Como as of today [49].

2.4.2.2. Airside Facilities

The Lake Como Seaplane base counts with only one waterway as in Figure 20 – waterway 19-01- with 1500 metres in length and 150 metres of width [51]. This waterway counts with the delimitation of its area by a corridor of 14 yellow buoys, as in Figure 21, that light up at night. At the head of the waterway, there are an additional 2 buoys. This area is reserved for the landing and taking off of amphibian aircraft with its crossing being extremely prohibited [52].

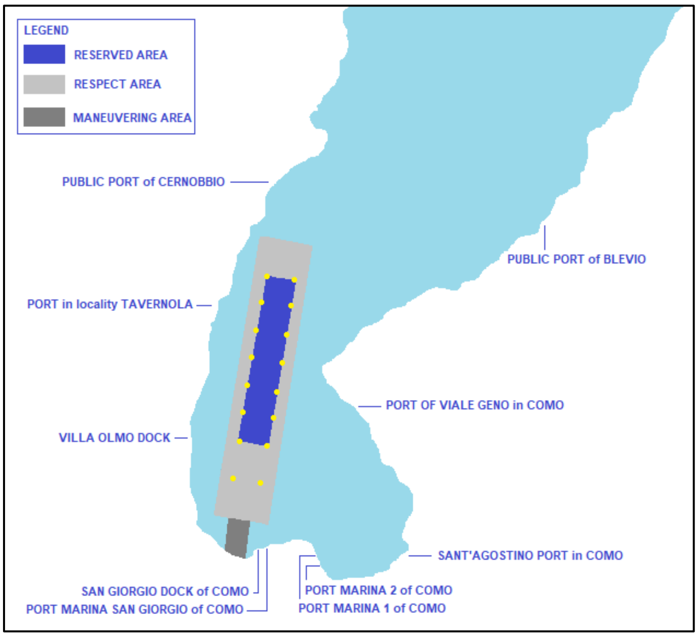

Figure 20 - Lake Como waterway diagram [52].

These buoys are anchored to the bottom of the lake by chains that are replaced on a regular basis.

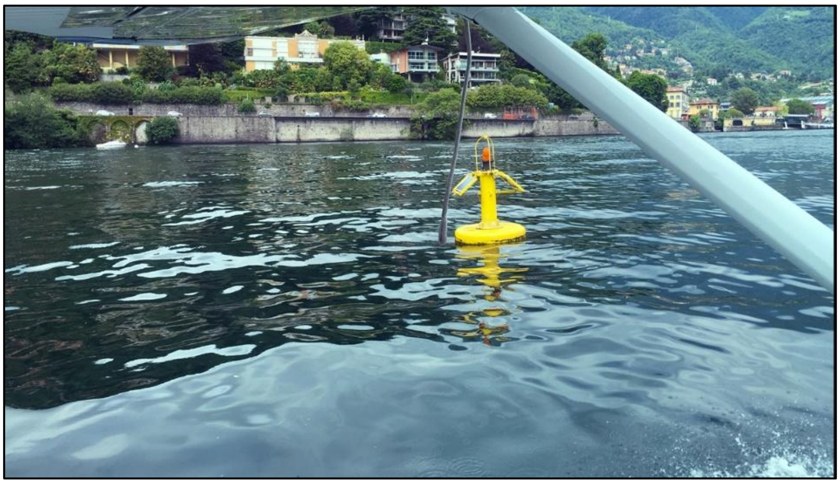

Figure 21 - Yellow waterway marking buoy at Lake Como [53].

The base provides a ramp to assist the manoeuvring of amphibian aircraft in and out of the water, and in the case of planes that aren't equipped with a landing gear, there is a small tractor that is able to tow the aircraft with the help of a movable platform placed under it. Additionally, the base provides 3 mooring floating platforms, one of them being able to accommodate 2 aircraft and the remaining ones being able to accommodate only one [54]. These are presented in Figure 22.

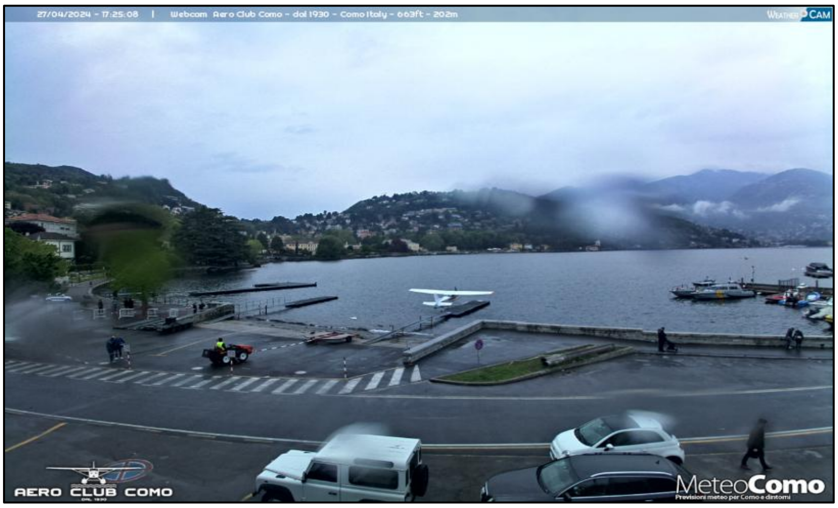

Figure 22 - Ramps and mooring platforms at Lake Como [55].

This is a VFR seaplane base, meaning that the operations should take place in VMC conditions. This is because the base does not have radio navigation aids. In spite of this, the base counts with a windsock to aid pilots to determine what speed and direction of the wind they should be considering when operating at the lake.

2.4.2.3. Landside Facilities

To store the aircraft, the Aero Club provides a hangar that can be also rented to host many events, some of them not related to aviation. Since the Aero Clube gives training, it also provides classrooms, a full workshop and a CAMO (Continuing Airworthiness Management Organisation) Certified maintenance workshop. This workshop not only provides maintenance services but also provides cleaning and refuelling ones [56].

For pilots wanting to save money, they have free accommodation with bunkbeds and a small kitchen [53]. The Aero Club also has a small parking lot in its vicinity and many coffees, restaurants and hotels that pilots can take advantage of. In spite of this, especially when comparing to larger seaplane bases like Lake Hood, the area of this base is narrow, with the aircraft need to share the public road with car and pedestrian traffic. As such, pilots need to be more aware when taxiing.

When an accident takes place in the nearby area, the Aero Club's aircraft also take part in the SAR rescue efforts.

2.4.2.4. Environmental Conditions

Regarding meteorological conditions, Lake Como has a humid subtropical climate [57], being warm in the Summer and cold in the Winter with the average temperatures around 23.8 Celsius degrees on the former and 4º Celsius degrees on the latter. Rainfall is abundant with an average of 130 centimetres per year. There is snowfall at least once a year, but it melts soon enough, and the lake never freezes. Regarding wind, is generally weak, being moderate only in the warm half of the year [58].

However, according to this organisation, they have a profound respect for the environment. This can be perceived by the constant presence of a wide variety of wildlife, such as aquatic birds. Since seaplane propellers don't come in contact with water, mechanical fluids are not spilled, turning structures like buoys piers an attractive option for waterfowls to build their nests. The Aero Club Como joined forces with the Italian Bird Protection League and together developed a birdwatching brochure for the Como Lake for the recognition of the fauna present [59].

2.5. Water Landing Procedures

2.5.1. General Context

Flying an amphibious aircraft is, in most ways, similar to piloting a land aircraft. However, the most notorious difference between landing in a static surface such as tarmac and landing in a mutable surface such as water is all the considerations to be aware off prior to the manoeuvre. The variables in this changing environment can be the water conditions, wind direction, presence of floating debris, boat traffic, among others [60].

2.5.2. Pre-Landing Considerations

The preparation for water landing begins before the actual flight take place. When the pre-flight is conducted, the pre-landing considerations should also take place. In this phase, if it's not a known seaplane base, pilots should verify the landing site to ensure that there is enough available length to land at a given speed. Details regarding the site reconnaissance while still flying, to search for obstacles, prior to the landing should be discussed as well. Additionally, the planning for beaching, approaching mooring sites or ramps should also take place [60].

2.5.3. Reconnaissance (Five W's Mnemonic)

The reconnaissance step is a crucial step prior to the water landing of aircraft. This step determines the suitability of the landing manoeuvre if the landing site is not known or unprepared for receiving aircraft. This is common during firefighting operations, for example, where scooping operations take place in dams or lakes available in the vicinities of the occurrence. In spite of this step that takes place during the flight phase, the key for a successful, safe manoeuvre is being aware of the conditions at the predetermined location prior to the mission. This ensures that the proposed location has que minimum requirements for the manoeuvre and also facilitates the reconnaissance during the flight.

Usually, this flight phase is composed by 2 parts. The high-altitude reconnaissance is normally carried out at 500 feet AGL, where flight crews preliminary assess the site. In this step, the Five W's mnemonic can be used:

- Wind/Water: Both of these factors are correlated. A pilot must assess the environmental conditions of the chosen landing site. This can be done using wind indicators, such as the presence of waves or wind streaks in the water. An illustration of this is presented in Figure 23;

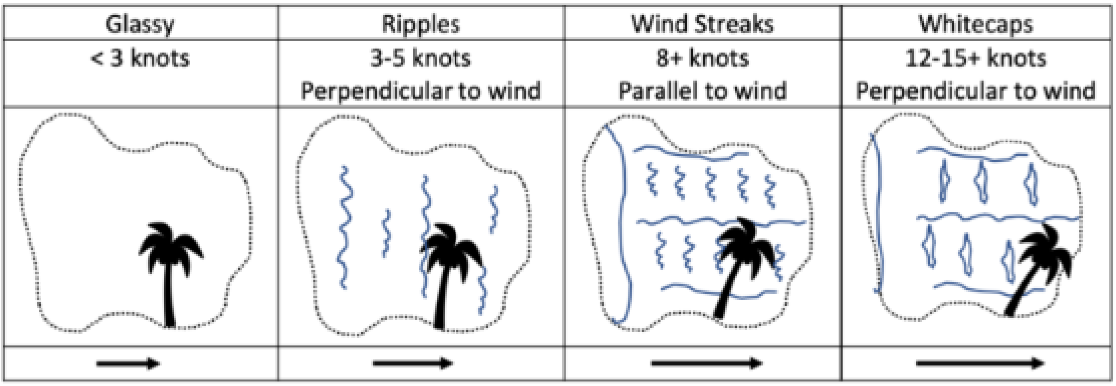

Figure 23 - Effect of wind on water [60].

- Wires: Suspended wires constitute a hazard to safe operations. This is due to their low visibility, especially under certain lighting conditions or poor weather;
- Way Out: In this phase, pilots must assess the strategy for departure. Additionally, if they decide to abort the manoeuvre, an abort point should be identified, and the alternative strategy must be decided as well;
- What If: Pilots should be prepared for unexpected situations such as the presence of boats, debris, jet-skis on non-airport environments. In this phase, the way to approach this situation should take place.

In this phase, pilots must not lose sight of the landing spot, avoiding the likelihood of mistaking the location chosen on the high reconnaissance to a similar one. Furthermore, pilots should position the aircraft in a landing attitude for the event of an emergency, such as loss of power [60].

The Five W's Mnemonic is useful while assessing the water landing location in real time. It is ideal that some support infrastructure is present, such as wind cones, to prevent pilots from assessing conditions based only on swells and nearby trees.

2.5.4. Normal Landing

In a normal landing case scenario, both the landing gear and the water rudders, if any, should be in the retracted position. A wheels-down landing gear configuration on water leads almost certainly to the capsize of the aircraft. The pilots should also, if possible, check visually the condition of gear-up [60], [61]. If not possible, pilots should consider a visual confirmation of this condition by nearby support personnel at the scooping location. Additionally, if a control tower is available, confirmation that the landing gear is down (they cannot confirm if it is locked, but the pilot can) by ATC could also be an option.

In this type of landing, pilots should position the aircraft into the wind, while controlling the speed and maintain stability with the ailerons, power and attitude setting. After contact with the water, pilots should maintain a slightly nose high attitude to counteract the tendency of nose down due to the increased drag on the floats. Generally, when the aircraft stabilizes, power should be cut off while the elevator is kept in the up position to maintain the propeller as far as possible from the water spray. Afterwards, if the aircraft is equipped with them, lower the water rudders to aid directional control of the aircraft on water [60]. It is important to mention that this situation depends for each selected aircraft. A scheme of these procedures is presented in Figure 24.

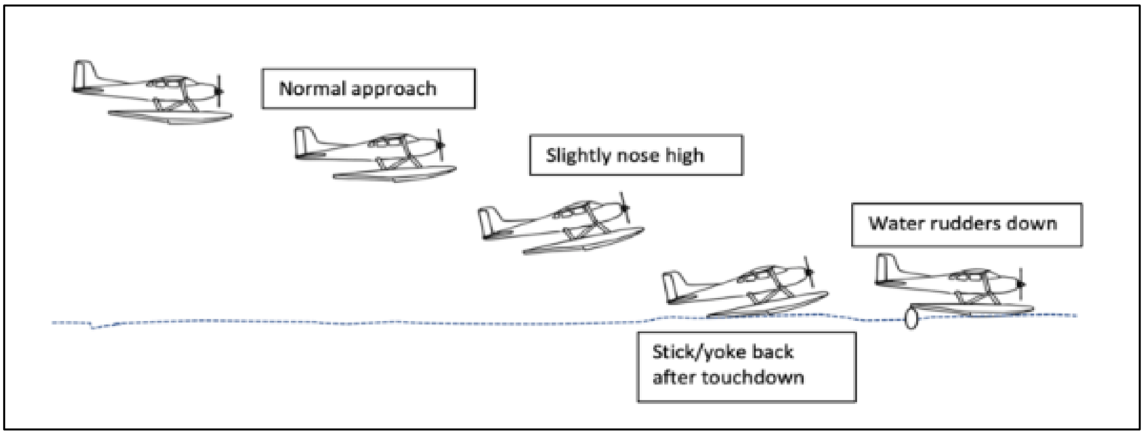

Figure 24 - Normal landing approach aircraft attitude [60].

It is important to note that the greater the difference of the speed between the aircraft speed and the contact surface, in this case water, the greater are the effects of drag resistance and as a consequence, the greater the tendency of nose down will be [60].

When landing, if the speed is excessive, and there is an improper pitch attitude, the skipping phenomenon can occur. This means that at touchdown, the plane bounces on the water. To stop this, pilots apply pressure on the elevator control, allowing the aircraft to airborne. After this, pilots stabilize the aircraft and try to land again with the proper attitude and speed.

2.5.5. Crosswind Landing

Amphibian aircraft should always land preferably into the wind direction. However, in some cases that might not be feasible due to traffic, obstacles on or under the water surface. Due to the presence of additional drag due to the flotation devices of the aircraft, even a small amount of drift on the water can cause significant sideways forces, leading to the aircraft capsize, as in Figure 25. This situation is aggravated by the combination of skidding force, wind and the tendency of the aircraft to weathervane. The amphibian aircraft's weathervane tendency is greater than the one of land aircraft due to the surfaces low friction characteristics when compared to land runways, and the lack of brakes. This is why, when crosswind landing, the goal should be always to minimize this lateral drift and maintain directional control after touchdown [61].

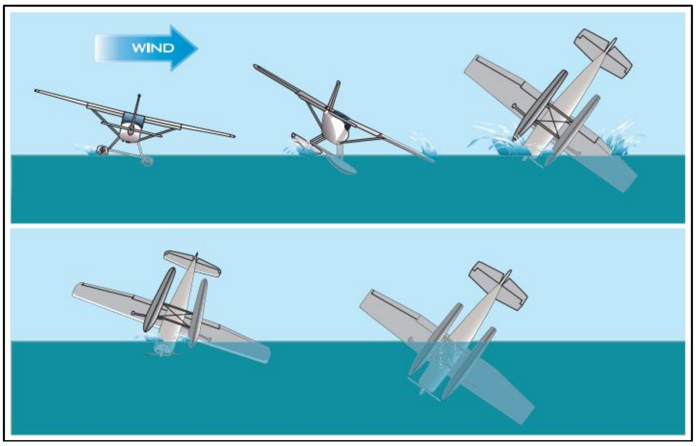

Figure 25 - Capsizing during extreme crosswind forces [61].

There are two techniques to compensate for crosswinds. The first technique is to lower the upwind wing while keeping the aircraft on a straight course with the help of the rudder. By dropping this wing, a horizontal component of lift is used do counter the crosswind drift, as in Figure 26.

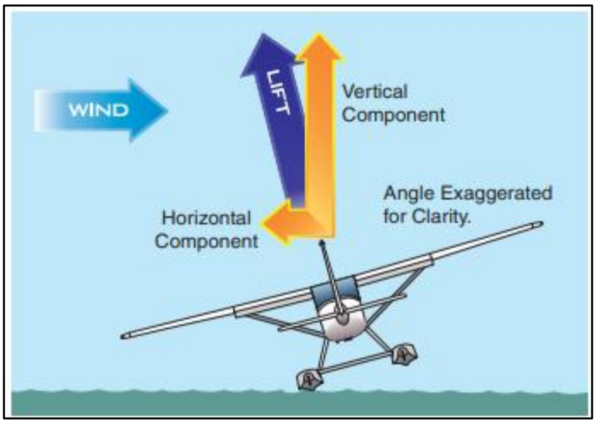

Figure 26 - Crosswind compensation technique [61].

After this, when the upwind float touches the water, the speed will be reduced significantly, and the other float will eventually touch the water due to the lift loss. Afterwards, the throttle should be closed to reduce speed and apply more aileron to keep the upwind wing lowered. As the rudder effectivity is reduced, the plane will weathervane into the wind. To reduce the applied forces on the aircraft, pilots usually steer the aircraft downwind to minimize the weathervane effects. When the aircraft is stable, pilots lower the water rudders for improved directional control.

The other possible technique is the downwind arc method. This method consists in creating a centrifugal force to counter the crosswind component, as in Figure 27. This can be achieved through choosing a curved landing path. The centrifugal force can be amplified or reduced by adjusting the rudder position. This manoeuvre requires experience from the pilots since the speed plays a significant role in it. The arc of the turn will become more pronounced the lower the speed. When the speed is very low, the aircraft will weathervane into the wind [61]. After this manoeuvre, the pilots can proceed to water steer with the water rudders, if any, the aircraft to the designated site.

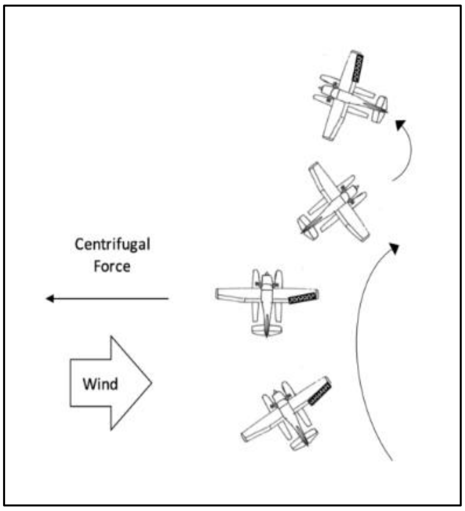

Figure 27- Downwind arc method [60].

2.5.6. Downwind Landing

This type of landing is rarely needed and usually only used when the wind speed is lower than 5 knots and on occasions where they are safer. When an aircraft lands with a downwind component, more water area is needed. However, this can be more practical in certain situations such as when an upwind landing means a longer, slower taxi back to the docking/mooring area [61].

The main concern on this type of landing is the increased groundspeed of the aircrafts. This increase leads to higher forces such as drag on the landing gear when the aircraft touches down. An increased drag means that the aircraft has more tendency to nose over. In low wind conditions this does not constitute a significant problem if the pilots know how the aircraft behaves when landing at higher speeds. On the contrary, with higher winds, the nose-down force may exceed the pilot's or flight control's ability to control the aircraft, flipping the aircraft over. In the extreme case of rough surface, the aircraft will be subjected to pounding forces on the floats and airframe [61].

2.5.7. Glassy Water Landing

This calm, mirror-like smooth condition of the surface of the water is due to the lack of wind. At first, it may seem that this is an optimal case for landing, however, glass water landing imposes a significant risk for pilots. The visual aspects mentioned affect depth perception, making it difficult for pilots to correctly judge the aircraft's height above water. In this situation, the pilot may flare too high, leading to a stall with high probability of the aircraft hitting the water with the floats and tipping over, as in Figure 28. On the contrary, if the pilot flares too low or not at all, the floats will be submerged due to the high speed and the plane will also likely tip over [61].

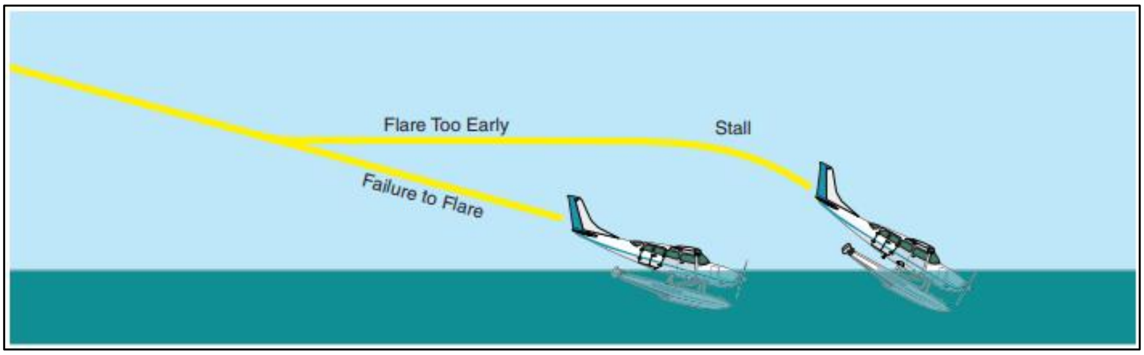

Figure 28 - Plane flipping over due to improper glassy water flare [61].

This condition of the water can affect pilots in diverse ways. As mentioned, the featureless surface of water can reflect the sky, clouds and objects in great detail. If the body of water is shallow of the waters are clear, the pilots may judge the altitude based on the bottom of that body of water, rather than the water surface. Additionally, since the water has no significant turbulence, when the aircraft touches down the experienced drag is greater than the one on disturbed waters since air bubbles between the floats and the water waves are not present, increasing the wet surface. This last situation can be managed with elevator control [60], [61].

To overcome the visual illusions created by glassy water surfaces, there are some techniques that pilots can take advantage of. Some of the simplest ones consist in land near the shoreline or making the final approach of the landing site over land. It's important to first assess the depth of the landing site since it is probably shallow and can have obstructions.

Other techniques involve a stable descent in landing attitude with a controlled descent rate for a gentle water contact. In this case, pilots should plan the landing early. In this type of landing, it is advised to land with power, with flaps and according to the aircraft manufacturer's checklist. A normal approach should take place; however, the pilots must prepare as though intending to land at a higher altitude above the surface to avoid unexpected, sudden contact. When the aircraft is ready to contact the water at the established altitude above the surface, the pilots should lift the aircraft nose and adjust the power setting to provide a constant descent rate, at approximately 10 knots above the aircraft's stall speed. The instruments should be monitored at all times and the attitude set in previous steps should be maintained until landing. The flare manoeuvre should not be conducted and as such, the aircraft should be fled onto the water in the landing attitude [60], [61]. Figure 29 shows how to properly land on Glassy Water conditions, by maintaining a proper aircraft attitude.

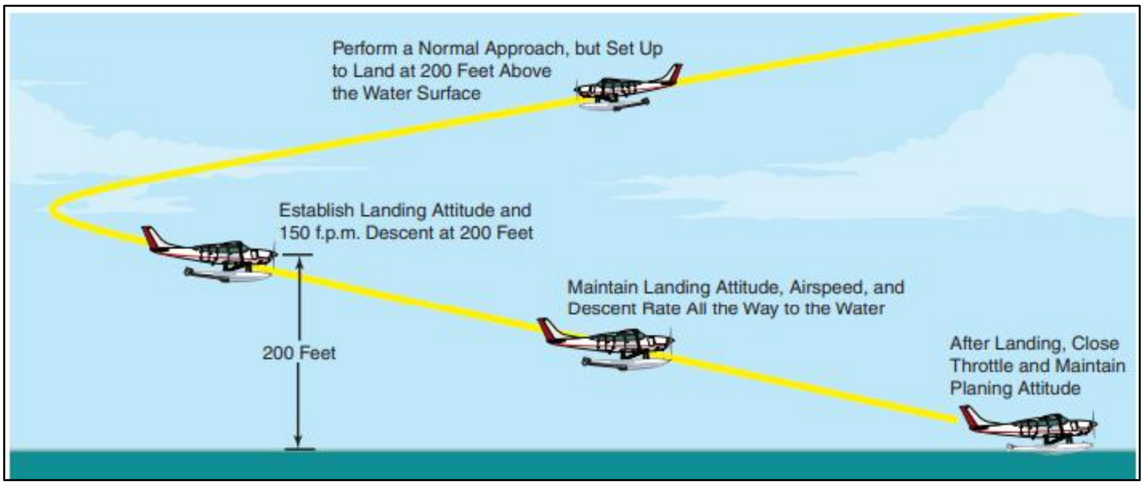

Figure 29 - Glassy Water landing correct attitude [61].

At this stage, pilots apply pressure on the elevator to maintain the pitch attitude and close the throttle only when the aircraft is completely on the water. This can be perceived through three different senses: vision, when the pilot sees the spray on the floats and a slight nose-down pitch, hearing, when the pilots hear the sound of the water and body sensation, when the pilot feels the deceleration forces. Accidents occurred in the past when the power was cut off after the initial touchdown and the aircraft had skipped, being airborne and stalled, causing substantial damage [61].

To conclude the landing, pilots can now lower the water rudders and taxi to the designated location.

2.5.8. Rough Water Landing

In spite of this term being relative and subjective to each pilot and each aircraft, there are important considerations regarding rough water landing. In the presence of rough water conditions, the pilot must consider both the wind direction and speed along with the water surface.

It is advised that pilots approach landing the same way as a normal landing, however, when close to the water, pilots must level the aircraft and increase the power just enough so when more acceptable conditions appear, power down and land. In the case of bouncing, pilots should increase the power setting to take off again and search for a more suitable, smoother landing spot. After finding it (ideally water runways should be clearly identifiable through visual markers, as it will be explained in the subsequent Chapter) and landing, it is advised to apply pressure on the elevator to prevent the front part of the float to dig under the waves. If, a larger wave hits the floats and makes the aircraft airborne again, pilots should apply full power to go around [61].

In strong winds, an upwind landing is preferred for a lower touchdown speed and shorter water run, minimizing stress on the floats and airframe. Additionally, landing on rough water can lead to the aircraft capsize. The combination of pitching and rolling provoked by the water conditions and the wind can lift a wing, tipping the aircraft over [61].

2.5.9. Confined Area Landing

The main concern regarding this kind of landing is usually the take-off run. Most amphibian aircraft have a shorter landing run than the take off one. This is why pilots need to verify not only the landing, but also the take-off conditions. Shallow areas, obstructions or other hazards should be identified prior to the landing. Another important aspect of a confined area landing is to be sure that the aircraft's climbing capability allows the aircraft to exit of that area or even to go-around during landing. If the terrain around the water body rises faster than the aircraft can climb, there is a great chance of collision. If this is the case, the pilots must verify that there is a chance to make a turn back over the water for climb [60], [61]. Furthermore, mitigation actions can take place in order to clear the confined area for safe landings. If this is not possible, it is necessary to ensure proper procedures that outline the specific flight conditions (predetermined altitude and heading at a certain location) to clear this area safely.

2.5.10. Go-Around and Emergency Landing

Pilots must execute a go-around manoeuvre when the conditions for landing are not favourable. This is the case when hazards present on the landing area are found, the atmospheric conditions are not appropriate or even when an aircraft mechanical failure takes place. When the decision to go-around is made, pilots should climb to a safe altitude, perform the go-around checklist and evaluate the situation. Depending on the location, sometimes it is advised to turn back over the water instead of over the shoreline, for example [61].

For amphibian aircraft, emergency landings comprised within gliding distance to a water body usually mean a low difficult landing, however, water and weather conditions should be analysed to land with the proper techniques and emergency gear.

If an emergency situation occurs while over land, pilots should search for a soft surface to land such as a smooth field or a snow-covered ground. Additionally, pilots should do a flatter, faster, win-facing landing, with power assisting if available to maintain the flatter attitude. Night water landings are discouraged due to visibility challenges and as such, lighted airports should be searched and used if available. An emergency landing on a runway presents little or no damage to the floats (if landing gear is not available), however, after touchdown, full elevator should be applied to counter the nose-down effect due to the rapid deceleration of the aircraft. Additionally, a low power setting should be used to provide airflow over the elevator to help keep the aircraft's tail down.

In case of emergency, the passengers and crew should be as prepared as possible. Before the landing, they should be briefed to the landing and post-landing emergency procedures and be equipped with flotation gear and emergency gear, such as rafts if available. The post-landing procedures should include instructions on how to exit the aircraft and use the provided emergency gear. Moreover, all doors should be unlatched to prevent door jamming due to airframe distortion resulting from a strong impact [60], [61].

2.5.11. Landing Amphibians on Land

Landing an amphibian aircraft is, in most ways, similar to landing a retractable gear aircraft, however, there are some necessary considerations to take into account. This manoeuvre requires the pilot to carefully check the position of the landing gear. Since the nose wheel is not as strong as the main wheel, it is required to keep them off the runway as long as possible. Additionally, it is advised to use aerodynamic brakes instead of wheel brakes to avoid early replacement and maintenance costs. Pilots used to land regular aircraft have the tendency to flare amphibian aircraft late since they generally sit higher off the ground. Additionally, knowing the aircraft crosswind limitations is imperative since these type of aircraft suffer greatly from crosswind due to the additional surface area because the presence of the floats. Moreover, since most aircraft of this type is equipped with caster wheels, when approaching taxi speeds, crosswind tends to push the nose due to the reduced friction between the wheels and the runway [60], [61].

During crosswinds that exceed the limits of the aircraft, an alternative runway should be selected or if a suitable location is available, water land into the wind.

2.5.12. Postflight Procedures

2.5.12.1. Anchoring

This procedure, considered to be the easiest, consists in securing the aircraft with a heavy anchor attached to the aircraft with a line. The tension on the line secures the aircraft, preventing drifting. The holding properties of the bottom are to be considered. It is necessary to be assured that the anchor is holding. This can be verified by looking into two fixed distinct objects in line with each other and watching if they remain aligned. It is also advised that the length of the line is around seven times the water depth. To prevent drifting, if the infrastructure is available, pilots should consider mooring the aircraft. It is also important to note that Anchoring is a suitable solution in the presence of light winds and for a short amount of time [60], [61].

When anchoring the aircraft, it is needed to consider the wind shift effects on it. It is necessary to anchor the aircraft in a place so that when the wind shifts, it does not collide with objects in its proximity. Pilots should also secure the elevator down and the rudder in neutral position to prevent amplified aircraft wind interference and response [61].

2.5.12.2. Mooring

This method uses a stationary surface structure, that can be a floating buoy, a pier or a floating raft to secure the aircraft. This structure is attached to the bottom of the water body through a heavy weight and a cable or chain and is equipped with elements to secure the aircraft. The initial contact with the mooring facility should be made with a boat hook or a with a person standing on the float deck. If there is a person assisting the mooring operation, pilots should be extremely cautioned to prevent the propeller from hitting them, since most aircraft have floats passing the propeller arc [61].

2.5.12.3. Docking

Docking is similar to mooring; however, the structure is permanent and fixed to the shore. In general, the procedures to dock the aircraft are the same as the ones executed on mooring. The more relevant difference is that approaching directly into the wind might not be feasible. For this reason, a careful docking planning should be addressed. In this case, pilots should find a way to counter the environmental conditions to prevent expensive damages. Either way, the approach to the dock should be made into the wind for as long as possible. It is advised to shut down the engine as soon as is clear that the aircraft could make into the facility by coasting [61].

2.5.12.4. Beaching

The solidity characteristics of the shoreline mainly dictate the suitability of this procedure. This implies an inspection of the beaching site, however, if not possible, it is advised to approach the beach at an angle to allow for manoeuvring back into deeper water if necessary. Rocky or muddy shores can damage the floats, so this situation must be considered. If the aircraft is equipped with water rudders, they must be raised while into shallow waters to prevent damage as well. Additionally, waves and shifts in tides must be considered since they could lift and drop the aircraft and change its position, respectively. Before the departure, the wheel wells must be verified to ensure that they are debris free. Debris in this area can prevent the correct function of the landing gear [61].

When strong winds are expected, the flight crew can tie down the aircraft using ropes on the available hooks on the wings and fill the floats with water. The latter option, even though effective, can be time and work consuming when pumping out water operation is carried out [61].

2.5.12.5. Ramping

Ramping is performed through a ramp, a sloping platform extending under the water surface. If this slope is made out of wood, amphibian aircraft without a landing gear can climb it, if it is wet. When the aircraft has a landing gear, a concrete ramp can be used as well. Water rudders, if installed, should be raised when the aircraft contacts the ramp to prevent damage [61].

Wind direction greatly impacts ramping operations. Pilots should maintain enough aircraft speed in the water while facing downwind (if not possible, pilots must approach the ramp downwind as possible and cut power off so that the aircraft weathervanes, allowing it to face the ramp) so that the aircraft is still manoeuvrable. This speed should be maintained until contact and while the ramp is climbed. If the speed is not maintained, the risk of weathervane and collide with the ramp sideways is significant. If this situation occurs, the aircraft should be taxied out to retry ramping. If the speed is maintained, the wave created underneath the floats cushions the impact, preventing damage. If the pilot applies little power just prior to the contact, the front of the aircraft raises, maximizing this effect. At all times, is necessary to hold elevator control all the way back throughout the ramping process [61].

If available, amphibian aircraft can also make use of towing vehicles to assist the climb.

2.5.12.6. Salt Water Considerations

In order to minimize corrosion effects due to saltwater operations, the aircraft must be washed with fresh water to eliminate salt residues [61].

2.6. Water Landing Training

Due to the operation differences already exposed in this chapter, pilots must obtain an amphibian aircraft rating to be able to pilot them. This additional training ensures pilots that additional manoeuvres that differ from land aircraft are addressed and trained. This ensures their proficiency in operating in the water environment, considering all the additional variables associated with it. In Europe there are many flight organisations specialized in this specific training and operation.

2.6.1. Baltic Seaplane, Germany

This flight school is currently an approved training organisation by the Schleswig-Holstein state Aviation Authority [62].

The basic Seaplane Training (SEP) consists of three parts:

1. Theoretical training: general instruction and related test;
2. 8 block hours of a Cessna 172P amphibian training;
3. Test flight with a flight examiner.

The advanced Seaplane Training (SEP) programme includes:

1. Theoretical refresher of knowledge of approximately 1 hour;
2. 3 block hours sea flight with a Cessna 172P Amphibian variant;
3. Tailored content training: Beaching, Docking, Glassy Water Landing/Takeoff, Confined Area Procedures, Rough Water Procedures, among others.

The school mentions that sport boat license is useful, however not mandatory and training must be completed withing 6 months to comply with EASA specifications [62].

2.6.2. Aquitaine Hydravions, France

This is an approved flight school by the DGAC – Direction Générale de L'Aviation Civile [63].

Their training programme consists of at least 9 flight hours and a final competence test. According to demand, classes can be individual or in group [63].

2.6.3. Aero Club Como, Italy

Aero Club Como is a flight school that can also provide SEP training for pilots [64].

The school demands at least 8 training flight hours with an instructor and the examination consists in a 1-hour final exam. This school also has the authorization to revalidate this kind of licenses [64].

2.7. Chapter conclusion

The examples of aircraft accidents related to water landings or ditching presented in this chapter highlight significant gaps in Portuguese emergency support infrastructure, which currently, and according to the reports presented, rely heavily on the occasional presence of nearby individuals during SAR operations.

In order to address this gap, two different existing infrastructures were presented. The Lake Hood Seaplane Base, in Alaska is the largest one of its kind and as such is extremely well equipped with operational and support infrastructure carefully placed to better aid pilots flying to this location. Since the water landing infrastructures to be proposed in this dissertation are going to be proposed in a dam, a smaller sized amphibian aircraft base was researched. The Lake Como Seaplane Base in Italy evidenced that even with fewer infrastructure the regular flying and training operation is still feasible by contemplating the key aspects regarding the available equipment on-shore, shoreside and off-shore. This ensures that safe flight activities are carried out effectively, even with minimal infrastructure, by prioritizing essential operational elements and strategic resources, such as a maintenance hangar and commodities for pilots.

It was also evidenced the importance of a careful, detailed pre-flight phase with proper water landing site assessments, including evaluation of water conditions, potential obstacles, and hazards such as flying birds or electrical power cables. To complement this, the need for new procedures to be included in basic pilot training regarding water landing procedures is key to ensure that such manoeuvres, whether in emergencies or regular contexts are performed safely. For this reason, general guidelines for amphibian aircraft operators and ATOs shall be provided in a way that the specific operational requirements of each operator can be added subsequently. This ensures that safety protocols and training are tailored to their unique contexts while maintaining a standardized framework for compliance and best practices.

3. Chapter 3 – Regulations for Water Landing Infrastructures and Water Landing Training

3.1. Chapter Introduction

There are vast examples of infrastructures, with some of them being so specific that just to find common ground between them, reveals a serious challenge. In spite of this, in order to develop any kind of infrastructure, the applicable regulations should be researched and thoroughly analysed to ensure the proper levels of safety and compliance. By highlighting the regulations background and context, a simplified view of them can be provided, along with a straightforward approach.

In this Chapter, the applicable International, European and Portuguese regulations are addressed by this order to perceive their specificities regarding water landing infrastructures and water landing training. Additionally, their limitations are also exposed, making the study of this chapter follow existing guidelines developed by State Members to standardize water landing infrastructures to an acceptable level of safety.

Furthermore, the Risk Assessment stage is also addressed to show its relevance in this context. Every operator shall define a Risk Assessment phase that establishes an acceptable level of risk exposure, correlated to the specifics of the operation. This phase should also be controlled to ensure that the measures to mitigate risk exposure are being effective and ensuring safe operations.

3.2. International Regulations

3.2.1. ICAO Annex 14 and Document 9157 – Aerodrome Design Manual

Designated as Annex 14, the International Standards and Recommended Practices for Aerodromes was adopted in 1951 [14], in accordance with Article 37 of the Chicago Convention [27]. This document outlines the minimum physical characteristics, object limitations, necessary facilities and technical services usually provided at an aerodrome and also Safety Management guidelines, by considering the aircraft operating at the site or that are planned for introduction. The ICAO Annex 14 is divided into two Volumes:

- **Volume I – Aerodrome Design and Operations;**
- **Volume II – Heliports.**

As such, Annex 14 has as a primary goal: help ensure uniformity and safety in aerodrome operations across the world. However, it is important to note that it becomes an appropriate state authority, the responsibility to evaluate and consider the particularities of each aerodrome to be developed. In order to enforce and complement the Annex 14 Standards and Recommended Practices (SARPs), for the design of aerodromes, ICAO issued Document 9157 [15].

This document, known as "Aerodrome Design Manual", provides technical guidance and best practices for implementing specifications in Annex 14. It is essential for aerodrome planners, engineers and operators, by helping to ensure that the SARPs outlined in Annex 14 are effectively and consistently applied across the global aviation industry. Document 9157 provides a more comprehensive reference, by offering more practical and detailed supplementary guidelines regarding aerodrome planning and design.

The ICAO Document 9157 [15] is divided into 4 parts:

- **Part 1 – Runways:** This part relates to providing a possible runway that ensures the safest and most efficient aircraft landings and take-offs. For this to be possible, it is necessary to consider the operational and physical characteristics of the aircraft expected to operate. Additionally, this first part also addresses the associated elements of runways, such as safety areas, runway shoulders and clearways, to name a few. This part also resumes the specifications and guidance material relating to their geometrical design [15];
- **Part 2 – Taxiways, Aprons and Holding Bays:** A well-designed taxiway system provides the increase of safety, efficiency and aerodrome utilization. By addressing modern aircraft capabilities, blast fence designs, holding bays, aprons and traffic segregation, this Annex part aims to help States implement the specifications uniformly [15];
- **Part 3 – Pavements:** Provides guidance on the pavement design by considering its physical characteristics, namely its bearing strength through evaluation and reporting methods;
- **Part 4 – Visual Aids:** To ensure a safe aircraft operation at the aerodromes/airports, visual aids become necessary and constitute themselves as a prerequisite for the safety and regularity of civil aviation. This part includes detailed guidance on the necessary visual aids characteristics used at the airports.

In spite of Annex 14 and Document 9157 providing guidelines for the development of aerodromes, it becomes clear that water aerodromes are barely mentioned in both of them. The only reference to water aerodromes is made on their Definitions Chapters: *"Aerodrome - A defined area on land or water (including any buildings installations and equipment) intended to be used either wholly or in part for the arrival, departure and surface movement of aircraft"* [14: 1-2], [15: 1-1]. For this reason, some states such as Canada, Saudi Arabia and Indonesia presented Working Papers on the 40th and 41st ICAO Assembly meetings, in 2019 and 2022 respectively, with the goal of increasing the efficiency and effectiveness of ICAO in this regard. These meetings are held at least once every three years, and all the 193 Member States and international organisations are invited to establish the upcoming three years Organisation policy [65].[7]

These papers mention that currently there are no globally accepted standards related to the design, certification and operation of water aerodromes since *"The Annex 14 Volume I – Aerodrome Design and Operations does not differentiate between land and water as a surface from which aircraft can operate and defines that an aerodrome is defined as area on land or water intended to be used either wholly or in part for the arrival, departure and surface movement of aircraft"* [66:2], [67:2]. Because of this aspect, several countries have developed their own regulations for water aerodromes. These regulations could serve as a basis for ICAO SARPs regarding the design, certification and operation of water aerodromes [67].

According to the October 4th, 2019 Doc 10140 - Assembly Resolutions in Force [68:II-49], the ICAO Assembly requested the council *"within the current allotted budget, and as a matter of priority, to review existing SARPs related to aerodromes and to develop specific Standards and Recommended Practices in the appropriate Annexes to the Convention in order to address the design, certification, management, safety and reporting requirements for water aerodromes operations"*. This request was made again on October 7th, 2022 during the ICAO Assembly that followed, as per Doc 10184 - Assembly Resolutions in Force [69].

Since at the time of the writing of this Dissertation there were no developments in this regard, documents already developed by the FAA and ICAO Asia and Pacific Office (APAC) and by the will be analysed in the following subchapters.

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[7] The Autoridade Nacional de Aviação Civil (the Portuguese National Authority of Civil Aviation) was also contacted regarding the existing gaps on applicable regulamentation and legislation of Water Landing Infrastructures. The Portuguese Authority confirmed also that this gap exists on both international (ICAO and EASA) and national regulations and as such, complementary documentation shall be researched, since ICAO Annex 14 does not provide full recommendations in this regard. However, the proposed infrastructures shall comply with the requisites established by this document and also with the Portuguese Decree-Law No 186/2007, of May 10th, that will be analysed later on this Chapter.

3.2.2. FAA Advisory Circular 150/5395-1B

In 2018, the Federal Aviation Administration (FAA) issued an Advisory Circular – 150/5395-1B - with the purpose of providing assistance and guidance to operators to plan, design, develop and implement seaplane bases with its necessary facilities.

This document aims to answer some questions such as the ones that follow [70:1-1]:

1. *"When a community determines the need for a seaplane base, where should it be located?*
2. *Given that the site has a suitable water operating area, what types of shoreline and off-shore facilities are available?*
3. *If a community improves its seaplane base with on-shore facilities, what design items are important?".*

3.2.2.1. Site selection

When performing the site selection for the base, it's necessary to consider several factors regarding different areas affected by its construction and operation.

The location and the size of the base depend primarily on the performance and number of the most demanding aircraft expected to operate, the presence of obstacles and wildlife. The water currents and consequent wave presence, the water depth, obstacles under its surface and physical characteristics of the shoreline should also be evaluated. Additionally, local regulations and noise limitations, prevailing wind direction, the presence of nearby aeronautical infrastructures and public accessibility also should be considered [70].

Regarding approach and departure paths, large obstacles and populated areas present hazard for a safe operation. As such, a clear over water path for both manoeuvres is recommended. If straight-in paths are not feasible, an over-water climbing turn or let-down procedure should be conducted. In the case of impossibility to remove obstacles, they must be highlighted with marking or lighting [70].

It is advisable to have currents of not more than 3 knots on landing and take-off areas. If this value is higher, such as 6 knots for example, assistance boats are usually needed to be provided to prevent aircraft from drifting away. These strong currents also present a higher difficulty for pilots to moor or utilize docks and ramps. Regarding water-level variations, if this phenomenon is expected, floating support infrastructure or less inclined beaches need to be addressed [70].

The bottom of the desired location needs to be analysed, not only for the presence of obstacles or shallow areas, but also for the characteristics of the soil. The first aspect mentioned is important specially on artificial lakes, such as dams, because at the time of flooding, the majority of trees are not removed and impose a significant risk. The second aspect is important to prevent aircraft to beach, or in an extreme case, prevent accidents. The later one is important to the development of the foundations needed for a proper securing of infrastructure or aircraft anchorage [70].

An environmental analysis is also important to access the impact of operation in water quality, wildlife, noise and air pollution. Services, such as fuelling facilities need also to comply with local pollution regulations, since spills may cause harm to natural life. Furthermore, wind studies can be based on local wind recordings, however, if not available, data obtained by local airports or meteorological organisations can be used and compared with real data gathered by direct observations. These considerations must access all ranges of wind conditions, weather and temperatures. Only daylight wind observation should be conducted if the seaplane base is not going to support night operations [70].

3.2.2.2. Off-shore facilities

Off-shore facilities are crucial for the operation of aircraft inside the water. These facilities account water lanes, taxi channels and anchorage areas. Designing these areas by considering land regulations may be problematic due to the differences of aircraft operation. Since water cannot be marked as is the case for land runways/taxiways, it is recommended to incorporate safe and object free areas in the project dimensions [70].

To determine the waterway dimensions, the most performance demanding aircraft to operate at the base should be determined. Since it is a difficult task to relate land runway/taxiway design regulations with the water ones, pilot operations handbook from the aircraft mentioned could be a feasible way to access overall dimensions. In order to do so, the Maximum Take-Off Weight (MTOW) case should be the one to be considered. It is necessary also to consider that the take-off run distance is usually greater than the landing one. Obstacles in the vicinity must respect the following considerations [70:3-3]:

1. *"If the seaplane base only serves visual approaches, the distance to the 50 feet obstacle will be 1,000 feet, based on a 20:1 visual approach and departure slope.*
2. *If the sea plane base supports instrument approach procedures, the obstacle is assumed at 2,000 feet from departure threshold based on a 40:1 instrument departure surface.*

3. *Objects that are shorter and closer may penetrate the 20:1 or 40:1 surfaces and need to be taken into account if present".*

Figure 30 denotes these considerations in a visual illustration.

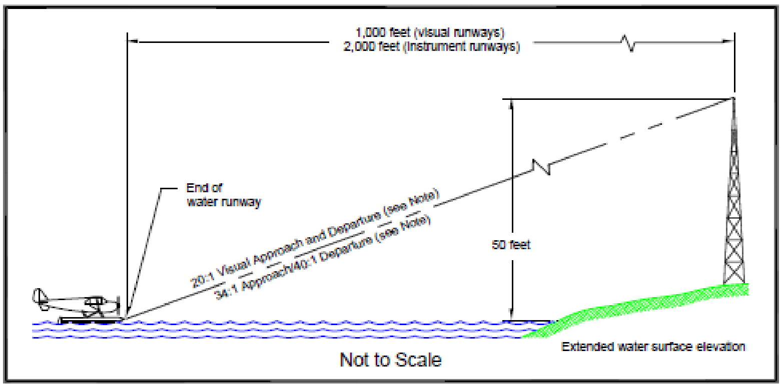

Figure 30 - Waterway Obstacle Clearance [70].

Since length measurements were already covered, the width is now to be addressed. The FAA AC 150/5395-1B states that *"when there are no constraints on the width of the water runway, 200 feet wide is considered a reasonable minimum width for most seaplane bases"* [70:3-3]. This width is considered to be sufficient to accommodate the majority of aircraft by considering, not only the water runway area, but also an adjacent runway safety area, as well as accommodating variations in water and wind conditions. It is also necessary another adjacent area that is clear of obstructions. This area can be, but it is not intended for aircraft operation. It is called the Object Free Area (OFA). In constrained areas, the water runway design should be maximized without compromising aircraft taxi. If back taxi is required, additional attention to incoming traffic is necessary.

Regarding water depth, it is advised a minimum of 4-feet depth and is recommended a 6-feet one. In open water, objects that intersect this minimum depth should be removed. However, if not feasible, they should be identified through visual markers or buoys.

Marking the water runways can be optional, however, not doing so might comprise in some disadvantages. If the water runways are not marked, the pilots can take full advantage of the water operating area, by adjusting to the current environmental conditions at the site. The disadvantage of this option is that existing guides regarding obstacle identification cannot be applied because an unmarked water runway does not have a defined threshold. Marking water runways not only provides safety but also helps identify them for other users. In fact, according to 14 Code of Federal Regulations (CFR) Part 77.3 document, *"seaplane base is considered to be an airport only if its sea lanes are outlined by visual markers"* [71:A-2]. Without clear marking, calculating approach and departure surfaces is difficult, risking intrusion of airspace by buildings or structures. As such, water runways should be marked with at least two buoys at each end, making thresholds and widths. Their alignment should consider prevailing winds, shorelines and water currents to maximize wind coverage and avoid obstructions. Regarding the installations of buoys, in the United States, it must be coordinated with federal, State or local governmental agencies, such as the U.S. Coast Guard [70].

Regarding Taxi Channels, they should be aligned with the prevailing wind to facilitate the taxi operation to the anchorage area, ramp or dock. The recommended dimensions are the following [70:3-8]:

1. *"Minimum width: 125 feet (recommend 150 feet);*
2. *Minimum depth: 4 feet;*
3. *Wingtip to Wingtip Clearance for passing seaplanes (dual directional taxi channels): 50 feet".*

Extra wide water manoeuvring areas, called Turning Basins, are also required to allow easier turning or mooring manoeuvres considering variations in the environmental conditions. Turning Basins should be implemented near the shoreline facilities entrances/exits and in both ends of the water runways. These should have a minimum diameter of 200 feet (60 metres) with an additional 50 feet (15 metres) to clear obstacles in the vicinity. Furthermore, they should also allow aircraft to make complete 360 degree turns. An example of implementation of the mentioned areas, is depicted on Figure 31.

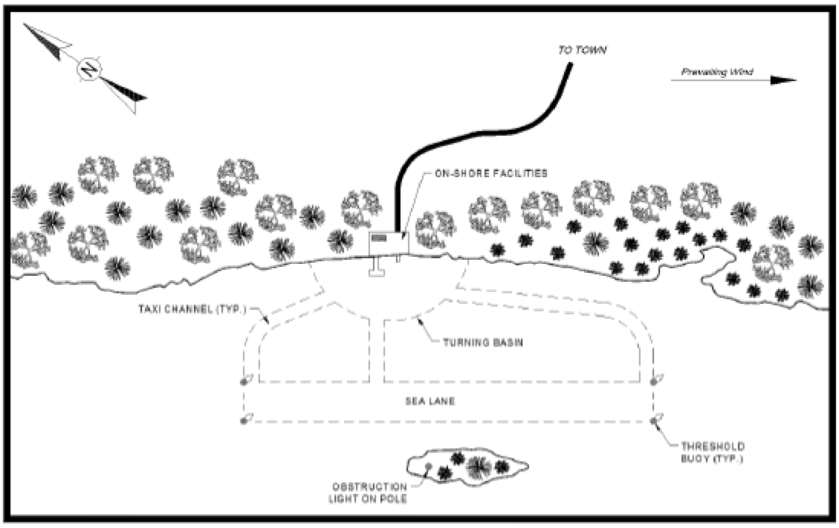

Figure 31 - Example of a Constricted Sea Lane and Taxi Channel [70].

For proper aircraft securement, anchorage areas must be outlined. For this to be feasible, information of the bottom characteristics should be provided for pilots. These areas, if possible, should be placed near docks or ramps. The diameter of the circle designed for aircraft anchorage should be the length of the anchor line plus 125 feet, with an additional 100 feet for larger aircraft, to avoid hitting other aircraft or obstacles. These areas can be

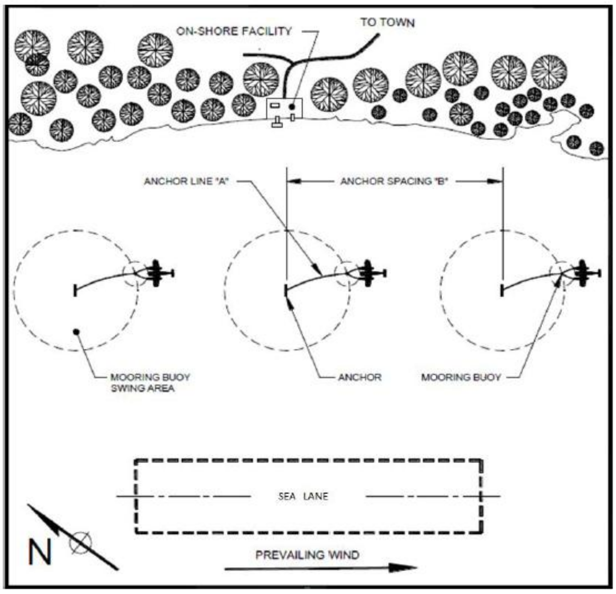

Figure 32 - Example of Anchorage area with permanent Mooring Buoys Swing Areas [70].

transformed into permanent ones if anchoring buoy is placed. Considerations of changing water-level should be also addressed to prevent aircraft from being left aground in lower tide. An implementation of these areas is proposed in Figure 32.

3.2.2.3. Shoreline facilities

Shoreline facilities are located both in land and in water and allow amphibian aircraft to load, unload and being secured, for example. With them, this can be accomplished without removing the aircraft from the water. They can also be adjusted do accommodate the operator’s necessity while considering the site’s topography.

For public use, these facilities can be:

1. <u>Ramps:</u> Sloping platforms that extend under the water surface and they are usually made out of concrete or wood. They should be placed in such way that they face the prevailing wind and that, when the water level is at a lower condition, the ramp toe is submerged. Its dimensions need to consider the largest aircraft that is going to operate at the site and a vicinity area free of obstacles to ensure wingtip clearance. A ramp width of 30/40 feet (9/12 metres) can accommodate all amphibian aircrafts in general. Additionally, the slope should not be greater that 6:1. Also, 10:1 slope ramps are usually more onerous, and their greater length is usually not necessary. An example is presented on Figure 33.

Figure 33 - Example of a ramp [70].

2. Docks: This general term refers to any structure used to secure amphibian aircraft to a fixed facility such as the shoreline or the lake's bottom. The term usually refers to:
   - Dock: Fixed position floating surface connected to the shore by a ramp or a gangway. This surface can rise according to the tide present at the moment on the site;
   - Pier: Similar to a Dock, however it does not rise or lower with the variation of water-level. An example is presented on Figure 34;

Figure 34 - Example of a Pier [70].

   - Float: This is an independent structure not permanently affixed to land. Is usually made of floating materials such as styrofoam blocks, inflated bladders or logs;
   - Barge: Similar to a Float, is usually larger, serves in industrial applications and is made out of steel. Barges may be anchored directly to the shore or to a pier, with a ramp or some kind of connection to land to allow its access;
   - Wharf: Usually used by larger vessels, this structure that is similar to a pier cannot be used by amphibian aircraft. However, if a float is attached to it, it can serve this kind of aircraft.

Docks should be designed in such way that the dimensions are according to the number of aircraft expected to use the facilities. Alongside the dock, the length of the aircraft plus 20 feet (6 metres) should be considered to provide sufficient clearance between consecutive aircraft. If both sides of the dock are going to be used, a 10-foot (3 metres) wingtip-tip-wingtip should be provided. The height is related to the buoyancy of the dock's materials and should consider the aircraft's expected to operate height. All of the objects and machines needed to be installed on the dock such as electrical boxes and water faucets for example, should be lower enough to avoid hitting the aircraft wings. Additionally, the dock should have tiedown and dock fender systems. The first relates to cleats or bull rails for example. These should be dimensioned to accommodate provided rope's thicknesses. The latter should be implemented to avoid damages to the fragile aircraft's floats. These should be installed along the sides of the dock as well as above and below the water surface. Used car tires can be a relatively cheap and viable solution for this effect [70]. Examples of these systems are presented on both Figure 35 and Figure 36.

Figure 35 - Example of Cleat and Bull Rails tiedown solutions [72],[73].

Figure 36 - Dock with Tire Fender System [70].

If more than one mooring facility is going to be built, a minimum separation of 50 feet (15 metres) between the turning basin and adjacent units should be provided to allow safer engine-powered taxi manoeuvres [70].

3.2.2.4. On-shore facilities

On-shore facilities such as fuelling services, hangars, public parking, for example should be implemented to complement aircraft operation. These must be assessed during the design phase and its number and size should also be tailored for the expected operation at the site.

According to FAA AC 150/5395-1B, *"any landside assessment should include at least three investigations"* [70:5-1]. The first one relates to available facilities at the public-use level such as electricity, water, internet/mobile coverage and sewage. Local sanitary codes should be also analysed. The second relates to the available road access to the seaplane base. Third and last one relates to the total space needed for the necessary installations. It is necessary to consider that landside facilities such as parking, stores should be separated from the airside ones such as aprons, tie-downs and hangars for example, via a buffer zone or fencing:

1. **Service Apron, Storage/Tie Down Area:** Ramps should be placed near service aprons and tiedown areas, minimizing taxiing conflicts. As mentioned, these areas should be separated from landside to avoid public access. As other facilities, their size also depend on the size and number of aircraft to operate with the addition of a few tie-down areas to serve itinerant aircraft;

2. **Hangars:** Regular land-based aircraft hangars are usually suitable for use of amphibian aircraft. To minimize taxiing issues, they should be located in such manner that their access is not compromised by tiedown areas or public spaces. In this case, their size also depends on the size and number of aircraft to operate. It is important to notice that hangars reserved for repair purposes should have facilitated access for maintenance material deliveries and staff;

3. **Fuel Service:** In the United States, fuel premises should comply with the U.S. Environmental Protection Agency, state and local regulations as well as the applicable fire safety ones. In general, there should be extra caution to ensure that a safe fuel storage and distribution, in addition to an effective fuel spill prevention programme are accounted for;

   Water presence on fuel can impose several risks to the operation, with the most severe case being an engine stop. As such, the following precautions are mandatory to prevent this type of fuel contamination [70:5-3]:

1. *"All tank opening subject to frequent opening and closing should terminate above ground, using recommended pipe extensions or spools;*
2. *Flush-type tank openings in paved areas should be kept water tight. Inspection and maintenance manholes that are subject to frequent opening should have flanged spool covers".*

If the tanks are above ground, a structure called dike should be implemented. An example is presented on Figure 37. This structure is a retainer around the fuel tank and should hold at least the volume of the tank. In case of more than one tank, its volume should be the one of the largest tank with an additional 10% of the total capacity of the remaining ones. Dikes should also have a drainage system to remove water from rain in a safe manner.

Figure 37 - Fuel tank equipped with a Dike [74].

Regarding a fuel dispensing system, it *"(...) usually consists of a pump, motor, strainer, meter, hose reel, hose, nozzle, automatic and manual control switches, and three-point, static discharge, electrical grounding equipment, all located above ground"* [70:5-4]. Electrical continuity of components and aircraft shall be guaranteed at all times by a grounding and bonding system. To avoid drips to fall on the water, a drip pan collection system should also be implemented on the nozzles.

4. **Hoisting Equipment:** Cranes or derricks used to lift aircraft from the water. It should be able to elevate at least 3 times the weight of the heaviest aircraft to be handled;

5. **Marine Railways:** Similar to the railways used by boats, these can remove the aircraft from the water with the help of a motor, rails and a platform, as in Figure 38. The depth that the railway should extend into the water is the same as the ramps used for this effect;

Figure 38 - Marine Railway used for an amphibian aircraft [75].

6. **Administration Building and Common Public Use Area:** These relate to the pilots/public comfort, such as restaurants, observation decks and administration buildings, to name a few;

7. **Parking Areas:** Should be implemented in such way that meets the public access demand and should be located in such way that a safe, convenient access to on-shore and shoreline facilities is guaranteed. Usually, the rule that is followed is: 1 car for each based amphibian aircraft, plus 1 for each employee and some for visitors, considering the local interest in the usage of the infrastructure;

8. **Road Access:** This is fundamental for the access of the public, staff and deliveries of several necessary items such as maintenance parts, fuel, among others. Road access should be studied to connect existing roads to the new ones to be developed.

3.2.2.5. Seaplane base visual identification

The identification of the base is necessary in night operations or in conditions of lower visibility. Additionally, some of the necessary equipment can be also used for daytime operations as visual aids to assist the operation.

Since water landing at night impose significant risks, it is not advised to perform one at those conditions. As such, water landing at night should only be carried out in emergency situations. This is due to the difficulty to judge altitude and to see objects at night. To minimize this issue, portable lights in buoys demarking taxi channels, turning basis, among others, could be a viable solution. For conditions of low visibility, a regular rotating beacon should be installed as well. A radio-activated beacon should also be implemented to advise marine traffic that oncoming aircraft is arriving or departing within moments. Regarding aprons, ramps, docks and other necessary installations, lights should also be installed for their illumination at night. These ones should be chosen in a way that their intensity does not affect the pilot's vision with distracting reflections.

The knowledge of the current environmental conditions, such as wind direction and intensity, is fundamental for a safe operation. As such, wind cones should be placed along and on the shore.

3.2.3. ICAO Asia and Pacific Office (APAC) – Guidance on Requirements for The Design and Operations of Water Aerodromes for Seaplane Operations

ICAO has divided the globe across 7 different regions to facilitate planning and implementations of ground services for international air transport. The Asia and Pacific Office is currently accrediting 37 states and is located in Bangkok, Thailand. They have been pioneers regarding water aerodrome design guidance. As such they have produced the *Guidance on Requirements for The Design and Operations of Water Aerodromes for Seaplane Operations* [16]. This document is based on the FAA AC 150/5393-1B [70] and much of its considerations are similar to the United States document.

It´s important to notice that this document only refers the *"minimum specifications for the physical characteristics, obstacle limitation surfaces (OLS), visual aids, services and operating procedures to be provided at water aerodrome for seaplanes operating maximum mass of 5700Kg and below*" [16:1].

3.2.3.1. Water Aerodrome Data

Water aerodrome aeronautical data should be provided with a certain degree of quality requirements. The rules that are advised to be applied, except when is specified otherwise, are as in Table 2.

Table 2 - Water Aerodrome data quality requirements [16].

Category	Measurement Accuracy
Elevation	Measured and rounded up to the next higher half metre or foot
Linear Dimensions	Measured to the nearest half metre
Coordinates	Latitude and longitude expressed in WGS-84 datum
Water Depths	Measured and rounded down to the nearest tenth metre
Tides	Measured relative to the lowest recorded tides

Regarding geographic data, accurate and consistent data collection is fundamental to ensure a safe and efficient operation. The requirements that apply to this data are as in Table 3.

Table 3 – Water Aerodrome geographic data [16].

Category	Measurement Accuracy
Geometric Centre	Determined to the nearest tenth of a second
Water Runway Elevation	Average highest elevation measured with reference to Mean Sea Level (MSL)
Magnetic Variation	Determined for the geometric centre to the nearest degree from Magnetic North
Navigation Aids	Bearing and geographic coordinates to the nearest tenth of a second, along with the elevation of the antenna or radiating centre

A series of dimension data should also be determined to ensure not only safe operations, but also essential for ensuring that all aerodrome facilities are adequately equipped and properly maintained, as in Table 4.

Table 4 – Water Aerodrome dimensions and relevant information [16].

Category	Measurement Accuracy
Water Runways	True bearing, length, width, water depth, and water current
Turning Basins	Location, dimensions, and water depth
Taxi Channel	Width and water depth
Shore Facility	Type and depth at shore
Significant Obstacles	Location, top elevation to the nearest higher foot, and type
Marking Details	Marking of water runways, taxi channels, and hazardous areas

Regarding the condition and status of the movement area and related facilities, see Table 5.

Table 5 – Water Aerodrome requirements for the provision of operational information [16].

Category	Description
Condition and operational Status	Information provided to aeronautical information service and air traffic services units.
	Operational significance details shared with appropriate air traffic services.
	Information kept up to date.
Monitoring and Reporting	Reports on operational significance affecting seaplane performance communicated to ATC units.
	Includes damage to shore facilities, floating debris, temporary hazards, abnormal water depth
	water currents, tidal areas, water depth variations, and other safety-related information
Information on Water Runway(s)	Tidal range details provided
	Times of high and low tide specified
	Approximate speed and direction of water currents indicated

3.2.3.2. Physical Characteristics

Concerning Water Runways, their number and orientation should ensure that for the majority of operational time (no less than 95%) at least one of the runways is suitable for amphibian aircraft landing and take-off operations, accounting for crosswind components.

The Water Runway length and width can be determined the same way as the FAA AC 150/5393-1B document [70] states. For the first, general operating aircraft performance and characteristics with additional corrections for the local conditions should be considered. For the latter, the advised 200 feet (60 metres) should be accomplished wherever practicable. It is also necessary to address a protective buffer zone, that extends 100 feet (30 metres) from the sides of the water runway and 200 feet (60 metres) from both ends.

This APAC document also accounts for water depth, turning basins, taxi channels, mooring areas and shore facilities, addressing the same aspects of FAA AC 150/5393-1B [70] and providing similar analysis. However, there are a few differences that should be highlighted:

1. Water depth:
    a. An additional constraint regarding the minimum 1-foot (0.3 metres) water runway depth clearance while the aircraft is stationary and loaded to the maximum take-off weight.
2. Turning basins:
    a. Diameter of no less than twice the water runway width instead of the 200 feet (60 metres) advised;
    b. An additional water depth of at least the one of the water runway.
3. Taxi channels:
    a. Water depth of no less than 6 feet (1.8 metres) instead of the 4 feet (1.22 metres).
4. Mooring areas:
    a. An additional constraint regarding the water depth of the mooring area that should be at least the one corresponding to the taxi channel.
5. Shore facilities:
    a. More requisites regarding provided platforms, such as good operative conditions to cause no harm to users, proper attachment to prevent position shifts, safe access from the shore and at least 2 bull rails or an appropriate number of cleats to each seaplane expected to operate;

b. When an hazardous condition, such as aircraft components hanging on the platform, is found, it should be visually marked through cones, hashed red and white markings;
c. Regarding Ramps, this document is more conservative, by stating that the ramp slope should not be steeper than 8:1 instead of the 6:1. Additionally, a well-defined value for wingtip clearance is provided: 6 feet (1.8 metres).

3.2.3.3. Obstacle Restriction and Removal

Either on a Land based aerodrome, or in Water based one, obstacle clearance should be addressed to avoid potential hazards on approach, landing, take-off and climb operations. As such, and also according to the FAA document previously analysed, an Obstacle Free Area should be implemented to protect the airspace around the infrastructure.

For non-instrument water aerodromes, a take-off climb/approach, transitional and inner horizontal surfaces must be defined as in Figure 39.

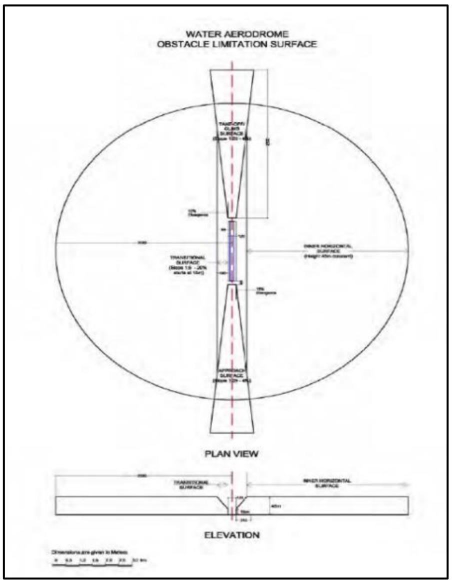

Figure 39 - Example of an Obstacle Limitation Surface definition [16].

Take-off climb/approach surfaces can be defined in 2 different ways, with either a straight-in or a curved path.

For both surface approaches [16:9]:

1. *"The width of the inner edge shall not be less than that of the associated water runway strip;*

2. *The inner edge shall start at 60 m from threshold of water runway;*
3. *The elevation of the inner edge shall be the elevation of the water aerodrome;*
4. *The length of the take-off climb /approach surface shall not be less than 2500 m (8200 ft.) from the inner edge;*
5. *The slope of the take-off climb/approach surface shall be a minimum of 4% (1:25);*
6. *The centre line of the take-off climb/approach surface shall define the approach path and be:*
    a. *a straight line; or*
    b. *an arc of constant radius; or*
    c. *a combination of a straight line and an arc of constant radius".*

For a straight-in take-off climb/approach surface, the divergence difference shall be set at 10% from the inner edge.

A curved approach is normally used where it becomes necessary to avoid obstacles, terrain, noise sensitive areas or in confined areas. It can become also useful to take advantage of public land airspace. This configuration should not contain more than one curve, and the curve shall not have an angle of more than 90 degrees, as demonstrated in Figure 40. It is also necessary to consider that *"the straight portion originating at the inner edge shall not be less than 1300 m (4265 ft)"* and that *"the radius of arc defining the centre line of the take-off climb/approach surface shall not in any portion of the take-off climb/approach surface be less than 736 m (2415 ft)"* [16:10]. Additionally, this should only be established where visual guidance/references are available.

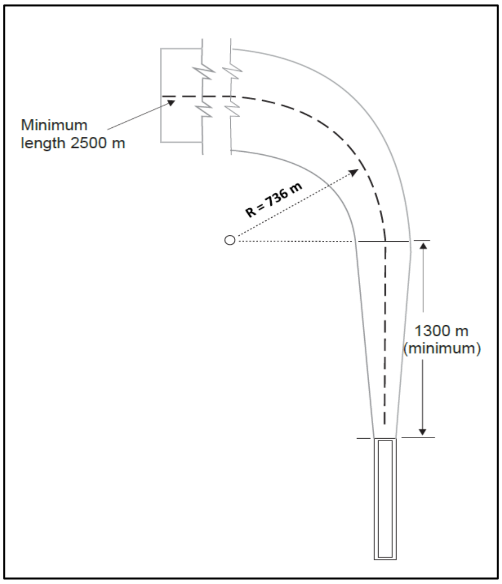

Figure 40 - Example of a curved Take-Off Climb/Approach Surface [16].

The general rules to be followed when designing operation areas can be followed through the resume Table 6.

Table 6 - Dimensions and slopes of obstacle imitation surfaces [16].

Approach type - Non-instrument	
Take-off climb/approach surface	
Width of inner edge	Width of water runway strip - (120 m minimum)
Location of inner edge	60 m from the threshold
Divergence take-off climb/approach surface	10 %
Length (minimum)	2500 m
Slope of take-off climb/approach surface (maximum)	4% (1:25)
Transitional Surface	
Slope (maximum)	Vertical to 15 m then (20%)
Inner Horizontal Surface	
Height	45 m
Radius	2500 m

A clear, obstacle-free approach should be implemented. The only obstacles that can eventually penetrate this area are the ones necessary for air navigation purposes and essential for the aircraft operation safety, the ones that are marked or lighted in accordance with ICAO Annex 14 – Volume 1 – Chapter 4 *"OBSTACLE RESTRICTION AND REMOVAL"* [14]. In this case, a safety risk assessment should also be conducted. Additionally, frangible obstacles, i.e. obstacles that are easy to break (boundary marks or signs, wind direction indicators, for example) are permitted as long as they don't constitute an hazard. Moving obstacles are allowed only if their removal during approach and departure operations is possible.

If a clear from obstacles area is not feasible, a runway displaced threshold – part of runway that is usable for an aircraft to land [76] – should be addressed. If this is the case, a distance of 200 feet (60 metres) between the inner edge of the approach surface and the point of displacement should be guaranteed.

The aerodrome operator should also perform a safety risk assessment to establish the necessary clearances.

3.2.3.4. Visual Aids for Navigation

Visual Aids help pilots to act according to the site physical and environmental characteristics present at the time to ensure a safe operation. According to this document, these can be in form of a wind direction indicator, markings, signs or strobe lights.

If wind direction information cannot be obtained through radio, at least one wind direction indicator must be placed. It should be painted international orange, orange/red and white, and shaped as a truncated cone. This visual aid should be visible from an altitude of no less than 1000 feet (300 metres) above the water runway and from any part of the manoeuvring area.

Regarding dock identification markings, it should consist of a triangular mark and if bull rails are installed, they shall be painted with international orange with white stripes. These should be also visible from 1000 feet (300 metres) above the water runway. Gangways should be painted indicating seaplane access only. They should be painted red or in alternative, signage should be provided.

For marker buoys, they should be visible to aircraft manoeuvring on the water surface and also from 1000 feet (300 metres) above the water runway.

If traffic or regulations are not an issue, both ends of the take-off and landing area must be marked with floating markers that are visible from over 2 nautical miles (approximately 3700 metres). These markers should be painted with international orange or international orange with white stripes. If this procedure is not feasible, guidance using geographical points or other visual references should be provided to designate the area, and they must be identified and published to the aeronautical community.

If a threshold is permanently or temporarily displaced, floating markers must be placed to indicate the renewed position, visible from at least 2 nautical miles (3700 metres). These markers should follow the paint scheme mentioned in the last paragraph.

In areas found hazardous that pose a danger to aircraft, marker buoys must be placed to clearly identify the hazardous area. Its colour should be different from the one used in water runway areas, to ensure proper differentiation.

Regarding prohibition signs, they must be posted on the dock to ensure that passengers are present in the docking area only when the aircraft propellers have stopped completely.

Strobe lights are also necessary and should be placed in such way that they are constantly visible to both marine and air traffic. These must be white and quick flashing.

3.2.3.5. Visual Aids for denoting obstacles

All obstacles, excluding the ones that are clearly and conspicuously visible shall be marked. If colouring them is not possible, markers or flags must be installed in accordance with ICAO Annex 14 – Volume 1 [14].

Markers placed on or near objects must also comply with guidelines. They should be placed clearly to maintain the hazardous obstacle visibility and should be identifiable from significant distances in clear weather conditions. They should be visible from 3280 feet (1000 metres) away while from the ground this distance shifts to 1000 feet (300 metres) from relevant directions. Additionally, their colour should contrast with the background.

3.2.3.6. Wildlife Strike Hazard Reduction

Since wildlife poses a serious threat to air operations, the presence of wildlife must be accessed through environmental studies. Likewise, and mitigation efforts must be carried out to reduce the likelihood of strikes and subsequent incidents/accidents.

3.2.3.7. Lighting of movement area

For reduced visibility conditions, or whenever found necessary, aerodrome lighting must be installed. An aerodrome can be identified by an alternating white and yellow beacon that flashes 12 to 30 times per minute. The same way that the FAA document analysed previously, also this one refers that a radio-activated beacon can be installed to alert marine traffic that an aircraft operation is imminent. Aprons, floats, ramps and docks should also be lighted carefully to avoid distracting reflections.

3.2.3.8. Rescue and Firefighting

At all aerodromes of this type, ensuring proper levels of safety and protection is required. As such, Rescue and fire-fighting vessels shall be provided according to the characteristics of the site and aircraft involved. These shall be able to carry twice the most demanding aircraft maximum passenger loading operating at the site.

The vessels shall be equipped with the necessary extinguishing agents and firefighting equipment as dictated by the aerodrome's attributed category, specified through ICAO Annex 14 – Volume I [14], as in Figures 41 and 42.

Aerodrome category (1)	Aeroplane overall length (2)	Maximum fuselage width (3)
1	0 m up to but not including 9 m	2 m
2	9 m up to but not including 12 m	2 m
3	12 m up to but not including 18 m	3 m
4	18 m up to but not including 24 m	4 m
5	24 m up to but not including 28 m	4 m
6	28 m up to but not including 39 m	5 m
7	39 m up to but not including 49 m	5 m
8	49 m up to but not including 61 m	7 m
9	61 m up to but not including 76 m	7 m
10	76 m up to but not including 90 m	8 m

Figure 41 - ICAO Annex 14 - Volume I - Table 9-1: Aerodrome category for rescue and firefighting [14].

	Foam meeting performance level A		Foam meeting performance level B		Foam meeting performance level C		Complementary agents	
Aerodrome category	Water (L)	Discharge rate foam solution/ minute (L)	Water (L)	Discharge rate foam solution/ minute (L)	Water (L)	Discharge rate foam solution/ minute (L)	Dry chemical powders (kg)	Discharge Rate (kg/second)
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
1	350	350	230	230	160	160	45	2.25
2	1 000	800	670	550	460	360	90	2.25
3	1 800	1 300	1 200	900	820	630	135	2.25
4	3 600	2 600	2 400	1 800	1 700	1 100	135	2.25
5	8 100	4 500	5 400	3 000	3 900	2 200	180	2.25
6	11 800	6 000	7 900	4 000	5 800	2 900	225	2.25
7	18 200	7 900	12 100	5 300	8 800	3 800	225	2.25
8	27 300	10 800	18 200	7 200	12 800	5 100	450	4.5
9	36 400	13 500	24 300	9 000	17 100	6 300	450	4.5
10	48 200	16 600	32 300	11 200	22 800	7 900	450	4.5

Note.— The quantities of water shown in columns 2, 4 and 6 are based on the average overall length of aeroplanes in a given category.

Figure 42 - ICAO Annex 14 - Volume I - Table 9-2: Minimum usable amounts of extinguishing agents [14].

The vessels should also be in possession of navigation aids, communication systems and medical assistance capabilities. Additionally, a robust communication network among local fire stations, control towers and emergency response units must be guaranteed.

Operational objectives shall aim for a response time of no longer than 3 minutes to any point on operational water runways, optimizing safety under clear visibility and clear surface conditions.

3.2.3.9. Water Aerodrome Emergency Planning

An Aerodrome Emergency Plan (AEP) for the water aerodrome must be prepared by the operator and issued for approval by the local regulatory authority. This plan *"shall provide for the coordination of the actions to be taken in an emergency occurring at an* *aerodrome or in its vicinity"* [14:9-1]. To do so effectively, the AEP should consider the objectives outlined in Chapter 9 of ICAO Annex 14 – Volume I [14], including at least [14]:

1. *"Types of emergencies planned for;*
2. *Agencies involved in the plan;*
3. *Responsibility and role of each agency, the emergency operations centre and the command post, for each type of emergency;*
4. *Information on names and telephone numbers of offices or people to be contacted in the case of a particular emergency; and*
5. *A grid map of the aerodrome and its immediate vicinity".*

In regard to the particularities of amphibian aircraft operation, the passenger evacuation in deep water should be considered. Additionally, the associated hypothermia risks and the effects of ingesting pollutants, such as floating fuel and oils and resulting vapours and fire suppressant foams, must also be taken into account. This emergency plan should also contain provisions for water rescue, fire response and recovery of disabled aircraft from the operational area.

The AEP needs to be consistently and periodically tested and reviewed to ensure the plan's adequacy and effectiveness, adhering strictly to ICAO Annex 14 – Volume I [14] guidelines.

3.3. European Regulations for building and certifying water landing Infrastructures: EASA 139 – Easy Access Rules for Aerodromes (Reg (EU) No 139/2014)

The EASA document 139 focuses on the certification and operations of EU Member States aerodromes. This document provides regulations, standards and guidelines to ensure the safety and efficiency of aerodromes within the European Union. This document also facilitates the compliance with international aviation standards, as the ones set by ICAO.

Since the establishment of this regulation, it faced several corrections and amendments. The most recent, the seventh amendment, was introduced by Regulation 2023/203. This amendment aims to add changes and provisions form information security risk assessment and management, as well as reaction to information security vulnerabilities and incidents and are applicable as of February 22nd, 2026 [17].

The key areas that this document addresses are the following: Aerodrome Certification, Aerodrome Design and Operations, Safety Management, Maintenance and Inspection, Emergency Planning, Personnel Training and Competence and Environmental Protection.

The EASA Document 139 is divided in 11 Articles that are complemented through 4 different Annexes, as in Table 7.

Table 7 - EASA Document 139 Articles and Annexes overview [17].

Articles	Annexes
Article 1 – Subject Matter and Scope	Annex I – Definitions for terms used in Annexes II to IV
Article 2 – Definitions	Annex II (Part-ADR.AR) – Authority Requirements for Aerodromes
Article 3 – Oversight	Annex III (Part-ADR.OPS) – Specific requirements for aerodrome operations
Article 4 – Information to the European Aviation Safety Agency	**Annex IV (Part-ADR.IMP) – Implementing Rules and Procedures**
Article 5 - Exemptions	
Article 6 – Conversion of certificates	
Article 7 – Deviation from certification specifications	
Article 8 – Safeguarding of aerodrome surroundings	
Article 9 – Monitoring of Aerodrome Surroundings	
Article 10 – Wildlife hazard management	
Article 11 – Entry into force and application	

This Subchapter provides a brief overview of every Article relevant for this Dissertation, that also refers to the related Annexes. As such, for more guidance information while applying these regulations, Annexes shall also be consulted for complete information.

For relevant design rules and figures, the responsible aerodrome planning entity should refer not only to the Annexes, but also to the final CS-ADR-DSN – Issue 6: Certification Specifications and Guidance Material for Aerodrome Design Chapter [17].

3.3.1. Article 1 – Subject Matter and Scope

This first article sets detailed guidance and rules for the certification and operation of aerodromes. This includes the conditions for establishing the certification basis while managing aerodrome certificates, including operation limitations related to the specificities of the aerodromes' design. This ensures the compliance with existing requirements, by defining responsibilities of certificate holders (Annex II, Annex III and Annex IV).

In this Article, acceptance and conversion of existing aerodrome certificates are also covered, as well as the criteria for managing exemptions and safety conditions for operations (Annex III). Furthermore, the procedures for declaring and overseeing apron management service providers (Annex II and Annex III).

This article concludes by stating that Competent Authorities involved in the aerodromes certification and oversight processes shall comply with the requirements of Annex II. Regarding Aerodrome operators, the provision of an apron management service shall comply with the requirements of Annex III and Annex IV [17].

3.3.2. Article 2 – Definitions

This Article establishes a number of relevant definitions for the purpose of the Regulation. By providing standardized definitions, clarity and common understanding of the specific terminology and rules application is ensured. This Article includes definitions for terms such as "aerodrome", "apron", "certification specifications", "safety management system", "obstacle limitation surface", to name a few of the relevant concepts necessary to the regulation's implementation [17].

3.3.3. Article 3 – Oversight

The 3rd article of this Regulation starts by stating that Member States must choose one or more entities as Competent Authorities with the powers and responsibilities for the certification and oversight not only of aerodromes, but also of operators, apron management service providers and personnel.

The designated authorities shall be independent from the entities mentioned above, to guarantee impartiality and transparency on the exercise of their powers. If multiple Competent Authorities are chosen, each must have clearly defined tasks and geographic areas, with coordination established to ensure effective oversight. These must have the necessary capabilities and resources to fulfil their regulatory requirements. Additionally, they are empowered to records, take copies, request on-site explanations, enter aerodromes and relevant premises, perform audits, investigations, assessments and proceed with enforcement measures as it deems necessary.

3.3.4. Article 4 – Information to the European Aviation Safety Agency

This relatively small article states: *"Within three months after the entry into force of this Regulation the Member States shall inform the European Aviation Safety Agency ('the Agency') of the names, locations, ICAO airport codes of the aerodromes and the names of aerodrome operators, as well as the number of passengers and cargo movements of the aerodromes to which the provisions of Regulation (EC) No 216/2008 and this Regulation apply"* [17:45]. As such, it was established a timeframe for the provision of data for the mentioned Authorities.

3.3.5. Article 5 – Exemptions

Regarding exemptions, such as non-compliance with the standards set, to this regulation, Member States are endowed to grant them. However, they shall notify EASA with the following information included: aerodrome details, operators and traffic figures. Each year, Member States shall review the traffic figures of these aerodromes and inform the Agency if traffic has exceeded the specified limits for three consecutive years. If this reveals to be the case, or if the safety objectives are not met, EASA can disallow the exemption given and the Member State shall revoke. It is important to reiterate that each Member State can propose exemptions to the compliance with this Regulation, and as such, the Portuguese ones are depicted further, on **Subchapter 3.4**.

3.3.6. Article 8 – Safeguarding of Aerodrome Surroundings

Safety impacts of proposed constructions within the obstacle limitation and protection surfaces and other relevant aerodrome' structures, shall be assessed by Member States. If there are constructions beyond those limits, Member States shall perform additional consultancy. In the case of the aerodrome being near the Member's border, neighbouring Member States shall be informed, and operations must be coordinated.

3.3.7. Article 9 – Monitoring of Aerodrome Surroundings

Regarding human presence in the aerodromes' vicinity, they must be assessed, and consultations must be conducted. Examples of human activities can be as follows [17:48]:

1. *"Any development or change in land use in the aerodrome area;*
2. *any development which may create obstacle-induced turbulence that could be hazardous to aircraft operations;*
3. *the use of hazardous, confusing and misleading lights;*

4. *the use of highly reflective surfaces which may cause dazzling;*
5. *the creation of areas that might encourage wildlife activity harmful to aircraft operations;*
6. *sources of non-visible radiation or the presence of moving or fixed objects which may interfere with, or adversely affect, the performance of aeronautical communications, navigation and surveillance systems".*

3.3.8. Article 10 – Wildlife Hazard Management

According to this Article, wildlife strike hazards must be assessed through [17:48]:

1. *"The establishment of a national procedure for recording and reporting wildlife strikes to aircraft;*
2. *the collection of information from aircraft operators, aerodrome personnel and other sources on the presence of wildlife constituting a potential hazard to aircraft operations; and*
3. *an ongoing evaluation of the wildlife hazard by competent personnel".*

ICAO provides a Bird Strike Information system (IBIS) database, where Member States are required to report these events.

3.3.9. Annex IV (Part-ADR.IMP) – Implementing Rules and Procedures

This Annex is the most relevant for this Dissertation, since it approaches the necessary services that an aerodrome operator or third party must provide. These must be integrated in the Safety Management System that ensures a safe operation.

This Annex is divided into 4 different Subparts - 3.3.1.9.1 to 3.3.1.9.4.

3.3.9.1. Subpart A – Aerodrome Data (ADR.OPS.A)

This Subpart states that the aerodrome operator shall assess, document and maintain data that is relevant for a safe operation, as well as all the necessary and provided services. This information shall be divulgated to the aeronautical community, air traffic services and aeronautical information service providers. This data should include, at least the following items [17:227]:

1. *"Aerodrome reference point;*
2. *aerodrome and runway elevations;*
3. *aerodrome reference temperature;*
4. *aerodrome dimensions and related information;*

5. *strength of pavements;*
6. *pre-flight altimeter check location;*
7. *declared distances;*
8. *condition of the movement area and related facilities;*
9. *disabled aircraft removal;*
10. *rescue and firefighting; and*
11. *visual approach slope indicator systems".*

Furthermore, information regarding obstacles inside and outside the aerodrome facilities shall be identified and provided as well.

This Subpart also refers to data quality requirements, coordination between aerodrome operators and providers of aeronautical information systems. It further addresses the following items:

1. Common reference systems;
2. Data error detection and authentication;
3. Aeronautical data catalogues;
4. Error handling requirements;
5. Metadata;
6. Data transmission;
7. Origination of NOTAM;
8. Reporting of surface contamination;
9. Reporting of the runway surface condition;
10. Information on the aerodrome lighting system;
11. Charts;
12. Information on radio navigation and landing aids;
13. Information on visual segment surface (VSS) penetration.

3.3.9.2. Subpart B – Aerodrome Operational Services, Equipment and installations (ADR.OPS.B)

The Subpart addresses the necessary services that should be provided by the aerodrome operator and if not the case, other organisations or State entities. Some of these organisations cannot be aviation related. However, if they are necessary, it becomes the operator's responsibility to assure that they provide services according with the applicable legal requirements. This external service provision needs to be compliant and integrated with the developed Safety Management System of the aerodrome. By doing so, the operators are discharged of responsibility when it comes to eventual non-compliances by the other entity involved.

In this Subpart, one can find the following services information:

1. Aerodrome emergency planning;
2. Rescue and firefighting services;
3. Monitoring and inspection of movement area and related facilities;
4. Foreign object debris control programme;
5. Wildlife strike hazard reduction;
6. Authorisation of vehicle drivers;
7. Authorisation of vehicles;
8. Operation of vehicles;
9. Aircraft towing;
10. Language proficiency;
11. Surface movement guidance and control system;
12. Communications;
13. Operations in winter conditions;
14. Operations on specially prepared winter runways;
15. Assessment of runway surface condition and assignment of runway condition code;
16. Night operations;
17. Operations in adverse weather conditions;
18. Fuel quality;
19. Visual aids and aerodrome electrical systems;
20. Aerodrome works safety;
21. Safeguarding of aerodromes;
22. Marking and lighting of vehicles and other mobile objects;
23. Use of aerodrome by higher code letter aircraft.

3.3.9.3. Subpart C – Aerodrome Maintenance (ADR.OPS.C)

As every infrastructure of this kind, the conditions are a determinant factor for safe and efficient operations and as such, maintenance is required. This Subpart outlines guidance specifications for the maintenance of vehicles, pavements, and other ground surfaces, as well as drainage systems, visual aids, and electrical systems.

It is important to note that the maintenance programme should consider human factor principles and the means for its effective implementation.

3.3.9.4. Subpart D – Apron Management Operations

Apron Management Operations relate to the regulation of aircraft movement to ensure that collision risks between aircraft and other aircraft or obstacles are mitigated. The aircraft entrance and exit operations shall also be addressed, including coordination with the aerodrome control tower, as well as safe vehicle movement.

This subpart also states that the following activities must be regulated [17:457]:

1. *"Aircraft stand allocation;*
2. *provision of marshalling services;*
3. *aircraft parking procedure and departure from the stand;*
4. *aircraft refuelling;*
5. *jet blast precautions and engine tests;*
6. *start-up clearances and taxi instructions".*

Furthermore, as defined in the Subchapter B, the operator may allocate these responsibilities to external organisations or entities by stating them in the aerodrome manual.

3.4. Portuguese Legislation for building and certifying water landing Infrastructures (Portuguese Decree-Law 186/2007 of May 10th)

According to **Subchapter 3.3.5 Article 5 – Exemptions** of the Reg (EU) 139/2014, Member States may propose exemptions. As such, in Portugal, national aerodromes must comply with this Regulation only if they meet the following criteria[8]:

1. If is for Public-use;
2. If it provides commercial air transport services;
3. If it has a paved runway (with approach and departure instrument capabilities) of at least 800 metres in length or those exclusively used by helicopters;
4. If it handles more than 10000 commercial air transport passengers per year;
5. If it handles more than 850 cargo-related movements per year.

Having these exemptions in considerations, the construction, certification and operation of Portuguese civil aerodromes regulations (that do not fall under this scope) is therefore

[8] This criteria was set by Autoridade Nacional da Aviação Civil. (2022). *Parecer sobre a Proposta de Lei n.º 39/XV/1.ª (GOV).*

consolidated by the Portuguese Decree-Law 186/2007, that was altered by the Portuguese Decree-Law 55/2010 of May 31st [19] and later on by the Portuguese Law 37/2023 of July 31st [20]. This Decree-Law is in many aspects outdated through new revisions of ICAO Annex 14 [14], as it will be outlined in 3.4.3.

This Decree-Law is divided into 6 different chapters – 3.4.1 to 3.4.6.

3.4.1. Chapter I: General Provisions

This first chapter sets the fundamental legal framework for the regulation of Portuguese civil aerodromes, either for fixed-wing or rotative wing aircraft. This regulation addresses the operational, administrative, safety requisites that are necessary for those infrastructures. It also sets different aerodrome types for different operations and aircraft types. In spite of this, as well as other documents analysed before in this Dissertation, this Portuguese Decree-Law do not address water landing infrastructures.

3.4.2. Chapter II: Construction and Certification of Aerodromes

The second Chapter of this Decree-Law is divided into 2 different sections, addressing both Construction, Expansion or Modification and certification of Portuguese aerodromes.

The first section states that any construction, expansion or modification of aerodromes need a prior approval from INAC – Instituto Nacional de Aviação Civil, that is now named ANAC – Autoridade Nacional de Aviação Civil [77]. A thorough evaluation of the project's feasibility, safety implications and environmental impact of the proposed project can be implemented by recurring to this section, while considering the indicated applicable Portuguese Laws. All of the topics addressed also comply with ICAO 3rd and 4th Annexes.

This section is constituted by 3 different articles:

1. <u>Article No 4 - Feasibility conditions:</u> The construction, expansion, or modification of aerodromes needs ANAC's approval; compliance with urban and operational safety regulations; compliance with the Portuguese Decree-Law No. 293/2003 of November 19th – Establishment of rules and procedures for introducing operational restrictions related to noise at community airports; compatibility with airspace usage (duly approved by the Portuguese Air Force); adherence to relevant laws and international standards, such as ICAO's Annex 14 [14].

2. Article No 5 – Preliminary feasibility assessment: An ANAC's approval based on a comprehensive feasibility assessment related to the construction, expansion, or modification of aerodromes is required. The process involves providing detailed documentation, favourable municipal and meteorological opinions, and adherence to operational, environmental, and regulatory standards, with appeals requests for revisions allowed to the relevant aviation authority.
3. Article No 6 – Project: The ANAC approval for a submitted project is mandatory. Their approval must be based on the applicable international standards and regulations, with defined approval timelines not exceeding 90 days after the project's submission, depending on the phase's complexity.

The chapter second section, is regarding certification requirements, details the necessary steps and conditions for obtaining an aerodrome certification by meeting the standards stated in the previous section.

3.4.3. Chapter III: Classification of Aerodromes

The aerodromes shall fit into one of the 4 established classifications. They are classified, by crescent order, from Class I to IV, depending on the aerodrome's *"... operational, administrative, security and facilitation criteria speacified in this Decree-Law; ...em função dos critérios de natureza operacional, administrativa, de segurança e de facilitação, constantes do presente decreto-lei."* [18:12].

The general requirements for each Class are the following:

1. **Class I Aerodromes:** Small, private, or recreational aerodromes with minimal infrastructure and services;
2. **Class II Aerodromes:** Often regional or local airports with basic infrastructure and limited services;
3. **Class III Aerodromes:** Generally, serve domestic flights and have fewer facilities than Class IV, but still meet high safety and operational standards;
4. **Class IV Aerodromes:** Typically include major international airports with extensive facilities, advanced communication systems, and robust emergency services.

It becomes relevant to address that this aerodrome classification is not in accordance with the one established in ICAO Annex 14 [14]. This document classifies the aerodromes based on a code of numbers and letters, corresponding to the characteristics of the operating aircraft for which an aerodrome is intended. The Code Element 1 (Code

Number) is referred to the aircraft's reference field length[9] and the Code Element 2 (Code Letter) is relative to the aircraft's wingspan. The combination of both Code Elements, provide a classification of the Aerodrome, as per ICAO Annex 14 [14].

3.4.4. Chapter IV: Use and Operation of Aerodromes

As the 2nd Chapter of this Regulation, also the 4th is divided into 2 different sections, the Aerodrome Operator's Obligations and the Exceptional Situations.

The first addresses the responsibilities of aerodrome operators, including regular audits and inspections to ensure the maintenance of compliance with defined standards. As such, operators are obliged to maintain accurate records and report any incidents to the Portuguese Aviation Authority: ANAC. This section also defines that all Portuguese aerodromes must have a Director that assures compliance with those standards and established procedures.

This Portuguese Decree-Law also states that temporary or permanent derogations can be granted. These special cases and their request process to the Authority, as well as particular conditions, such as prior communication to ANAC are addressed in the following Articles of this Chapter:

1. Article No 27: Permanent derogations;
2. Article No 28: Temporary derogations;
3. Article No 29: Operation of civil aircraft in military aerodromes;
4. Article No 30: Exceptional use of non-certified locations.

Regarding Article No 30, there are some key aspects to consider such as:

1. The need for prior authorization from the property owner or possessor;
2. The location must be outside urban areas as defined by municipal zoning plans;
3. No residential, leisure, educational, religious, healthcare, or livestock facilities within a 300-meter radius of the landing site;
4. The operation must not involve parking the aircraft at the location between sunset and sunrise;

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[9] The Aircraft's reference field length *"means the minimum field length required for take-off at maximum certificated take-off mass, sea level, standard atmospheric conditions, still air and zero runway slope, as shown in the appropriate aeroplane flight manual prescribed by the certificating authority or equivalent data from the aeroplane manufacturer. Field length means balanced field length for aeroplanes, if applicable, or take-off distance in other cases."* Retrieved from Reference [17:491].

5. The flight must comply with the air traffic rules established in Annex II of the Chicago Convention and other applicable regulations.

These requirement shall also be communicated to not only ANAC but also to the nearest police authority at least 24 hours in advance (both emergency situations and emergency operations conducted by State aircraft or in operation for the State are excluded from this). In spite of this, the responsibility for ensuring compliance with these requirements lies with the aircraft operator and the pilot in command.

3.4.5. Chapter V: Misdemeanour Provisions and Precautionary Measures

The 5th Chapter of this regulation outlines the available enforcement mechanisms to ANAC and other regulatory agencies. They are entitled to assess non-compliances with certification standards or operational regulations. These can include penalties, in form of monetary penalties or additional restrictions on the operation.

3.4.6. Chapter VI: Final and Transitional Provisions

The final chapter relates to the certification process for already existing aerodromes at the time of the publication of this regulation. The aim is to aid those operators to comply in a smooth transition manner with new regulations implemented by this Decree-Law. The transition is phased to ensure compliance without disrupting existing operations.

3.5. European regulations for water landing training

3.5.1. Regulation (EU) No 1178/2011

This European Union Regulation details the rules for pilot licenses, by addressing their issuance, maintenance, amendment, suspension, and revocation, as well as the conversion of national licenses. The certification of individuals responsible for providing flight and simulator training is covered as well. Additionally, the rules for issuance and management of different medical certificates for pilots, cabin crew, aero-medical examiners and for pilot training organisations and aero-medical centres.

This regulation is concluded with the specific requirements for flight simulation training devices and for the organisations that operate them. Furthermore, the requirements for administration systems for Member States, EASA and related organisations as well as specific annexes for ballons and sailplanes pilot licences are also addressed.

In Subpart H – Class and Type Ratings, the issuance of Type Ratings, the necessary previous certifications and requirements as well as Type Rating variants are exposed. Furthermore, the conditions for revalidation are also addressed [22].

In order to pilots being allowed to operate aircraft into water environments, they need to comply with previous training requisites. These prerequisites can be found in **Appendix A** of this Dissertation. When these mentioned prerequisites are met, the pilots can then apply for the specific type rating [22].

Regarding SEP/Sea Class Rating, there are two main components, the theoretical and practical parts. On both a minimum pass mark evaluation of 75% is demanded by EASA. On the theoretical test, it should be comprised of at least thirty multiple-choice questions. The instructors should have experience of this rating class category [22].

On the theoretical part of the course, pilots learn essential topics such as flight preparation, safe planning considering wind, tidal currents and presence of ice, water movements, critical techniques for landing, taking-off, taxiing and mooring. Additionally, float and water rudder construction methods and characteristics are addressed as well as inspection for leaks in the floats. Another important subject that is related to the theoretical training is the compliance with the rules about avoiding collisions at sea, related to sea charts, buoys, lights and horns [22].

Regarding the practical modules of the course, pilots should learn how to manoeuvre aircraft on water and mooring the aircraft, assessing landing, take-off and mooring areas while still airborne. They should also acquire the skills on how to assess the water conditions and their effect on the aircraft, as well as the effects of floats on aircraft performance and flight characteristics impact with floats equipped. An major factor that should be thought as well is the ability to land and taking-off under glassy water conditions, due to their increased risk [22].

Furthermore, an extensive list of knowledge topics that students must acquire can be found on AMC1 FCL.725.A(b) of the Reg (EU) No 1178/2011 [22]. The operator in charge of the operation and related training can follow Reg (EU) 965/2012 [23] for the necessary operational risk assessment and required additional equipment for water landing operations.

3.5.2. Regulation (EU) No 965/2012

This European regulation addresses all of the necessary technical standards and administrative procedures for commercial air transport operations within the European Union. This Regulation aims to ensure high levels of safety and compliance within the industry, by addressing topics such as Air Operations, Safety Management, Training and Competence and Audits and Inspections, to list a few.

Regarding this Dissertation, this document provides useful information related to the necessary operational risk assessment guidelines and necessary emergency equipment related to water landing procedures.

3.5.2.1. Risk Assessment

The Annex VII (Part-NCO - Non-Commercial Operations) of this regulation, refers to the air operation with other-than complex motor-powered aircraft and this Annex states that "*Before commencing a specialised operation, the pilot-in-command shall conduct a risk assessment, assessing the complexity of the activity to determine the hazards and associated risks inherent in the operation and establish mitigating measures*" [23:345].

The Risk Assessment phase should be developed into the SMS of the operator, in order to ensure safe operation. It should evaluate all possible hazards and, based on this assessment, classify whether the operation is safe. If not, it should be defined the level of acceptable risk for the operation [78].

The purpose of Risk Assessment in Safety Risk Management is not to make decisions, but to quantify and rank safety events, determine overall exposure from safety issue, proof of the completion of the risk assessment phase and track exposure.

This phase should consider also the 4 main pillars of Safety Risk Management [79]:

1. <u>Safety Policy and Objectives:</u> Establishes a proper environment for effective safety management. It should reflect the organisation's commitment to managing and ensure safety. Safety objectives and priorities shall be outlined and ensured through the commitment of the leadership/accountable managers or executives. They should establish an organizational structure with the proper resources to achieve safety goals. The responsibility and accountability, however, shall also be assigned across all levels of the organization;
2. <u>Safety Risk Management:</u> By identifying potential hazards, the mitigation and control measures can be enforced to mitigate operational risk;
3. <u>Safety Assurance:</u> Guarantees that the organisation's performance is according to the predicted safety goals and that the measures taken are effective;
4. <u>Safety Promotion:</u> The process of sharing information regarding safety trends, knowledge, good practices and lessons learned, for example. This should also be accompanied by two other practices: creating a positive safety culture and training programmes. The first one related to the encouragement of staff

participation in SMS by promoting a just, positive safety culture. The latter related to ensure the staff's competence to discharge their safety responsibilities.

There are several tools for understanding the risk exposure, and some known examples are the European Risk Classification Scheme (ERCS) [80] and the Aviation Risk Management Solutions (ARMS) [81], to name a few.

SEVERITY			CLASSIFICATION (ERCS Score)									
Potential Accident Outcome	Score											
Extreme catastrophic accident with the potential for significant number of fatalities (100+)	X	Pending Risk Assessment	X9	X8	X7	X6	X5	X4	X3	X2	X1	X0
Significant accident with potential for fatalities and injuries (20-100)	S		S9	S8	S7	S6	S5	S4	S3	S2	S1	S0
Major accident with limited amount of fatalities (2-19), life changing injuries or destruction of the aircraft	M		M9	M8	M7	M6	M5	M4	M3	M2	M1	M0
An accident involving single individual fatality, life changing injury or substantial aircraft damage	I		I9	I8	I7	I6	I5	I4	I3	I2	I1	I0
An accident involving minor and serious injury (not life changing) or minor aircraft damage	E		E9	E8	E7	E6	E5	E4	E3	E2	E1	E0
No likelihood of an accident	A		No Implication to Safety									
	Corresponding Barrier Score		9	8	7	6	5	4	3	2	1	0
	Barrier Weight Sum		17-18	15-16	13-14	11-12	9-10	7-8	5-6	3-4	1-2	0
			PROBABILITY OF THE POTENTIAL ACCIDENT OUTCOME									

Figure 43 - ERCS Risk Assessment Table
[78].

This Matrix (Figure 43) serves as an illustrative representation of the safety risk score of a determined operation, by relating the severity and probability of a related hazard [78].

In this table (Figure 43), the severity score is ranked with the following values "X, S, I, E, A" from the most severe, extreme case, to is counterpart, no severity. The same ideology applies to the probability ranks, that are evaluated from 0 to 9, on which 0 corresponds to the least probable case and the 9 the most likely one.

Every operation imposes its own specific risks and challenges, and for that reason there cannot exist a table that suits all organisations and operations. As such, when developing a Risk Assessment Matrix, there is the need to define an Acceptable Level of Safety that reflects the acceptable risk exposure for the specified operation.

3.5.2.2. Flight over water (NCO.IDE.A.175)

Regarding the operation of other-than complex motor-powered aircraft, the Regulation also makes some considerations about the necessary safety equipment when flying over water.

With respect to life-jackets, the aircrafts should be equipped with one per person onboard and it should worn or if not feasible, be stored in a readily accessible location from the seat. This is applicable to [23:336]:

1. *"Single-engined landplanes when:*
   1.1. *Flying over water beyond gliding distance from land; or*
   1.2. *Taking off or landing at an aerodrome or operating site where, in the opinion of the pilot-in-command, the take-off or approach path is so disposed over water that there would be a likelihood of a ditching;*
2. *Seaplanes operated over water; and*
3. *Aeroplanes operated at a distance away from land where an emergency landing is possible greater than that corresponding to 30 minutes at normal cruising speed or 50 NM, whichever is less".*

Regarding Seaplanes operating over water, the necessary equipment for the operation is the following [23:337]:

1. *"one anchor;*
2. *one sea anchor (drogue), when necessary to assist in manoeuvring; and*
3. *equipment for making the sound signals, as prescribed in the International Regulations for Preventing Collisions at Sea, where applicable".*

When relating to ditching events regarding the previous point 1.2, the pilot-in-command shall determine, by considering the occupants of the aircraft, the carriage of the following items [23:337]:

1. *"equipment for making the distress signals;*
2. *life-rafts in sufficient numbers to carry all persons on board, stowed so as to facilitate their ready use in emergency; and*
3. *life-saving equipment, to provide the means of sustaining life, as appropriate to the flight to be undertaken".*

3.5.2.3. Flight over water (NCC.IDE.A.220)

Regarding non-commercial air operations with complex motor-powered aircraft, (Part-NCC), the considerations are similar to the ones addressed on point 3.5.2.2.. In spite of this, there are some differences [23:300]:

- Regarding life-jackets, they should be equipped with means of electric illumination for facilitation of SAR operations;

- To what concerns seaplanes operating over water, they should be able to transmit *"sound signals as prescribed in the Regulations for Preventing Collisions at Sea, where applicable"*.

3.6. Portuguese regulations for water landing training – Reg No 164/2006 of September 8th

This Portuguese regulation aims to establish the applicable rules to what concerns the operation of civil, light aircraft. Regarding the operation of ultralight aircraft, it is regulated and enforced only through this national Regulation. The European Regulation presented in previous subchapters does not apply to them. The 31st Article is related to the obtention of seaplane or amphibian aircraft rating [82].

An important aspect to consider when analysing this Regulation is that the original Portuguese Regulation No 164/2006 of September 8th was superseded by Regulation No 510/2008 of September 18th [83] and by the Regulation No 147/2018 of March 8th [84]:

1. According to this Article, the amphibian aircraft rating can be obtained by satisfying some prerequisites. These are the following:
   1.1. Having received complementary theoretical instruction, in a training organisation approved by the national authority. The detailed programme can be found on the Annex XIII of this regulation;
   1.2. Having completed a Portuguese Authority approved flight training program as detailed in the Annex XIV of the regulation, and having performed at least 5 hours of flight in a Seaplane or ultralight amphibious aircraft, including at least 20 water landings and 20 take-offs from a water body, of which:
      1.2.1. A minimum of 10 water landings and 10 take-offs performed under dual control command instruction;
      1.2.2. A minimum of 5 water landings and 5 take-offs performed solo under supervision.
   1.3. Having presented a flight aptitude certificate issues by the training organisation where the instruction was conducted. This should certify the pilots' ability to operate this kind of aircraft in aquatic environments.
2. This rating certification can only occur if the license includes the corresponding land class rating for the seaplane or ultralight amphibious aircraft in which the instruction took place, or a type rating determined appropriate for this purpose by the Portuguese Authority;

3. This rating shall be included in the pilots' license with the authorization of seaplane or amphibian aeroplane operation properly stated.

The Annex VIII relates to the theoretical instruction programme for obtaining authorization to operate seaplanes or ultralight amphibian aircraft. It should focus on the following aspects [84]:

1. Legislation and Operational Procedures:
   1.1. Specific rules applicable to water operations;
   1.2. Applicable aspects of the International Regulation or Preventing Collisions at Sea, Recreational Boating Regulations and Reservoir Navigation Regulations;
   1.3. Obstacles to consider in inland water operations, submerged and floating obstacles and precautions to consider;
   1.4. Operation in glassy water, rough waters and crosswind conditions;
   1.5. Description of docking manoeuvres, mooring to a dock, floating docks and to a buoy. Additionally, the factors to consider when performing these kind of manoeuvres;
   1.6. Knowledge of the meanings of flags "A" and "B" of the International Code of Signals;
   1.7. Proper use of a life jacket.
2. General Nautical Knowledge:
   2.1. Applicable nautical terminology and nomenclature;
   2.2. Execution of common sailor knots;
   2.3. Tides, currents and winds. Consultation of the Tide Table. Beaufort Scale;
   2.4. Buoyage;
   2.5. Interpretation of nautical charts.

The Annex XIV relates to the practical training programme for the obtention of the authorization to operate seaplanes or ultralight amphibian aircraft [84]:

1. Movement over water;
2. Surface movement using wind;
3. Mooring to a dock, floating dock or buoy;
4. Normal take-offs;
5. Normal water landings;
6. Water landings and take-offs on mirror-like water;
7. Water landings and take-offs in rough water;
8. Water landings and take-offs with crosswind conditions;

9. Take-offs in confined areas.

3.7. Chapter Conclusion

By analysing the content of this chapter, it becomes clear that there are mandatory aspects to consider while designing water landing infrastructures. The same applies for the training that should be provided to pilots to operate at those sites.

By conducting a research of the applicable regulation, the lack of water landing infrastructures related content becomes evident, as it was highlighted by the Member States to which ICAO standards apply. This is also verifiable for EASA regulations. It was important also that this gap on the regulations is acknowledged by ANAC, that states that as of now, anyone who proposes the implementation of such infrastructure shall undergo a tailored process to ensure its certification. For that reason, by researching existing seaplane bases and the guidelines pursued by their operators - developed either by their ICAO regional offices or their home Aeronautical Authorities – one can extrapolate guidelines for Europe and Portugal.

For the second objective of this Master Dissertation, the European regulations are extensive to what concerns SEP/Sea Class Rating, addressing not only what should be thought at flight schools, but also what pilots should master when operating on the water landing context. These guidelines are followed strictly by the Portuguese regulations mentioned and can allow for the development of amphibian aircraft operation that relates with water landing procedures. It is also important to note that the regulations regarding ultralight aircraft, as of now, is only enforced through the presented national Regulations.

4. Chapter 4 – Case Study

4.1. Chapter Introduction

At the time of writing this Master Dissertation, no dedicated water landing sites exist in Portugal. As such, the content developed in this Chapter aims to address this gap by proposing the implementation of water landing infrastructures as two selected dams in the country.

By proposing these facilities, the dam's utility will be enhanced, by promoting water-based operations, contributing also for local economy. This development should consider careful planning and design to ensure that the infrastructures are safe, regulatory compliant and an asset for aircraft operation in Portugal.

As of today, dams are utilized by ANEPC for scooping manoeuvres in firefighting operations. By extrapolating this to civil aviation, not only regular water landing operations can be conducted, but also crucial emergency ones, related to emergencies in non-amphibian aircraft.

In the event of an in-flight emergency, such as engine failure, these sites could provide for a safe ditching option, when compared to uncontrolled water landings. Since the proposed infrastructure shall be equipped with emergency response capabilities, the safety of emergencies in flight operations in the region will increase by reducing the risks associated with emergency water landings.

For the Water Landing Infrastructure design, the Cessna 208 Grand Caravan EX Amphibian was chosen due to its high versatility, which includes an amphibian version. This is a single-engine turboprop designed and produced by Cessna, a commonly known and established manufacturer. This aircraft needs to be operated by two pilots and can carry up 10-14 passengers, making it attractive for tourism purposes. Additionally, since the design of such infrastructure should consider the most critical aircraft in terms of dimensions, it is not a large aircraft such as a Canadair, but not as small as a Cessna C152 [85].

The amphibian variant of the 208 Grand Caravan EX Cessna model (refer to Figure 44 for visual reference of the aircraft) has the dimensional and performance characteristics as in Table 8.

Figure 44 - Cessna 208 Grand Caravan EX Amphibian [86].

Table 8 - Cessna 208 Grand Caravan EX Amphibian Dimensional and Performance characteristics [85].

Dimensions	Wingspan	52 ft 1 in	15.87 m
	Length	41 ft 7 in	12.67 m
	Height	17 ft 5 in	5.31 m
Engine	P&WC PT6A-140	867 shp	Note: shp – Shaft Horse Power
Weights	Maximum Take-off Weight	9062 lb	4110 kg
	Empty Weight	5975 lb	2710 kg
	Useful Load	3122 lb	1416 kg
Performance	Take-off Ground Roll	1826 ft	557 m
	Take-Off Water Run	2000 ft	610 m
	Maximum Climb Rate	1212 fpm	369 mpm
	Maximum Cruise Speed	164 ktas	304 km/h
	Maximum Range	810 nm	1506 km

In Table 8, one can notice that there are no values for the Landing run. As stated in the Chapter 2 of this Dissertation, the take-off run distance is more critical for water landings due to the aggravated drag that amphibian aircrafts experience because of the presence of floats. As an additional note, the performance values for this aircraft are based on zero wind conditions. This aircraft is equipped with the Wipline 8750 floats, that have a hull hight of 3 ft 3 in (0.99 m) and a hull width of 3 ft 6 in (1.07m) [87].

To effectively take advantage of the newly proposed water landing infrastructures, specialized training for pilots and emergency response teams is essential. In this Chapter, the first will be assessed.

Water landings, particularly for non-amphibian aircraft in distress, pose unique challenges, not faced on in-land operations. Water landing training shall comprise a controlled landings and take-offs, ditching and safe evacuation procedures, while coordinating with on-site emergency responders.

By considering a comprehensive water landing training, this chapter aims not only to ensure that these requisites are met, but also to ensure that the proposed infrastructures can be used safely and effectively for both routine and emergency situations, consequently enhancing overall aviation safety in the region.

4.2. Portuguese Water Landing Operations - ANEPC

The ANEPC, is the responsible Authority for the coordination of civil protection and emergency response efforts in Portugal [26].

Every year, ANEPC releases a specialized operational framework, designed to coordinate and optimize the firefighting efforts in rural areas. This document is the DECIR – Dispositivo Especial de Combate a Incêndios Rurais [88]. DECIR operates on a seasonal basis, usually covering the May-October period, depending on the environmental conditions. Under the guidance of a centralised command, multiple entities such as firefighters, armed forced, civil protection units and local municipalities, develop efforts for the wildfire prevention, detection and suppression.

On the DECIR document, it is possible to perceive the strategical location of scooping points scattered across the country. The geographical coordinates of each scooping point serve only as a reference since according to Alexandre Benigno – *"the scooping manoeuvre does not resume itself to just a simple touchdown, but to a water refilling on a water body by a firefighting amphibian aircraft, by considering the following conditions: direction, orientation and wind intensity; direction and orientation of the* *load and the temperature"* [10]. Also, the characteristics of the aircraft to be used are also considered for the selection of the scooping points.

ANEPC utilizes mainly the Air Tractor AT-802F Fireboss and the Canadair CL215 for the firefighting efforts. The limitations for these aircraft are as in Figure 45.

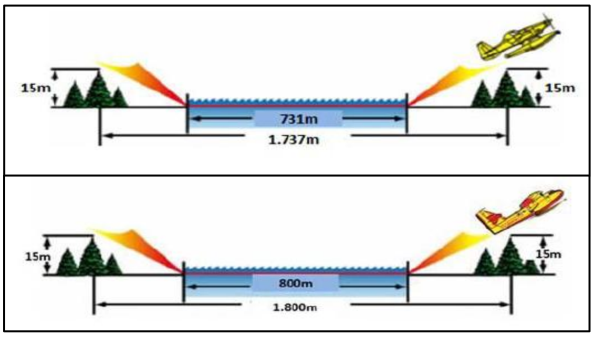

Figure 45 - Minimum required distances for scooping operations of the Air Tractor Fireboss (Up) and the Canadair CL215 (Down) [89].

Furthermore, the minimum permissible depth for the Fireboss aircraft is 0,5 metres and for the Canadair is 1,8 metres [89].

The chosen locations for water scooping operations are selected anually by the Comando Nacional de Emergência e Proteção Civil (CNEPC) in collaboration with Portuguese Maritime Authorities for locations within the public maritime domain, under the jurisdiction of the Maritime Delegations, and in collaboration with the Guarda Nacional Republicana (GNR) [90] in other areas of the public water domain. Those are depicted in Figure 46.

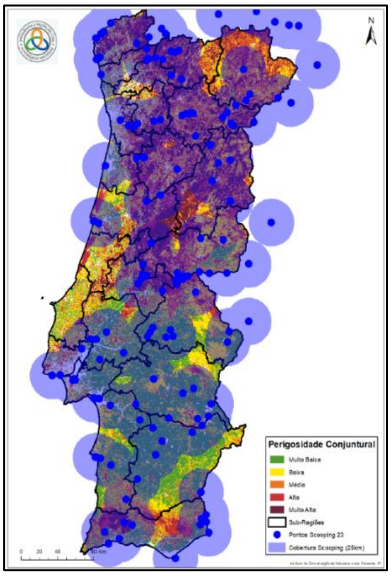

Figure 46 - Amphibian Aircraft Scooping Point Distribution for 2024 [88].

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[10] A. Benigno (personal communication, August 14, 2024)

Scooping operations are extremely demanding as concluded on the 2nd Chapter of this Dissertation. For this reason, bye comprehending their limitations, an extrapolation of suitable locations for Water Landing Infrastructures, through the current locations used for scooping operations can be addressed.

The Marateca and Aguieira Dams were chosen due to their proximity, both to Castelo Branco and Viseu regional aerodromes as well as to the University of Beira Interior. The projection of water landing infrastructures at these sites, could be the basis for the practical implementation of them.

4.3. Proposed Water Landing Sites in Portugal

4.3.1. Marateca Dam

4.3.1.1. Site Selection

The Santa Águeda Dam, also known as the Marateca Dam, is located between the cities of Fundão and Castelo Branco and at approximately 34 km and 12 km in straight-line distance to the University of Beira Interior and to the Castelo Branco Aerodrome, respectively. Both the location and a satellite view are represented in Figure 47.

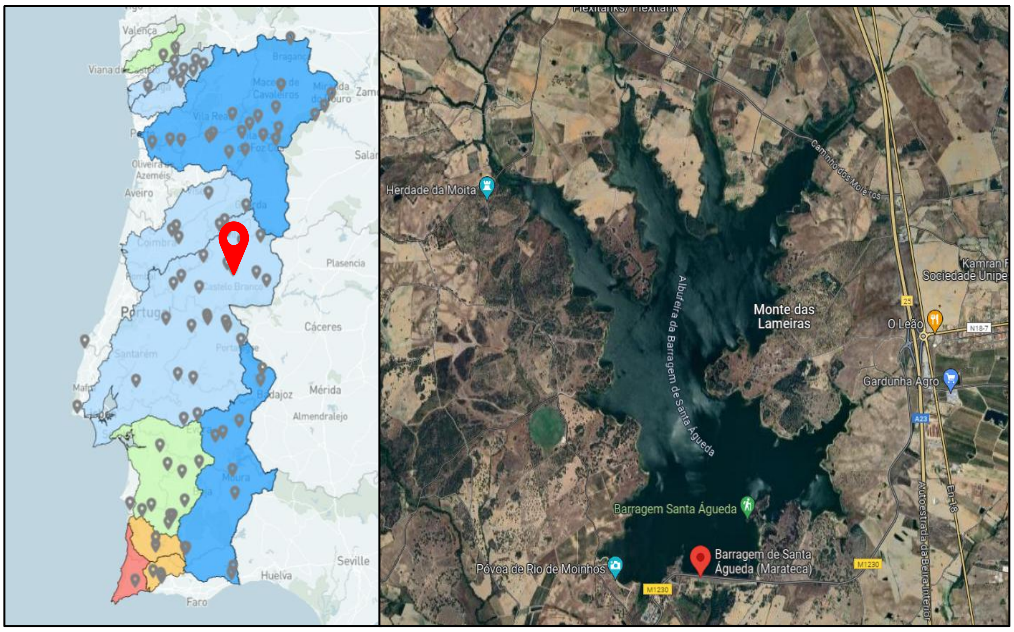

Figure 47 - Santa Águeda/Marateca Dam Location (Left) [91] and Satellite View (Right) [92].

This dam became operational since 1990, by enclosing the Ocreza River, a tributary of the Tagus River and its main purpose is to supply fresh water to the region's municipalities. At its maximum level, the flooded area is approximately 634 hectares. It is surrounded by gentle slopes, with nearby agricultural fields and pastures. This reveals that this could be a candidate for the implementation of water landing infrastructures.

In spite of this, wildlife is abundant at this place and as such, for considering the implementation of such infrastructure, can be challenging in this regard. This forces the developer to ensure that wildlife mitigation efforts are being carried out [93].

For the dam to be able to accommodate a runway, a certain length based on the most critical aircraft to be used at this water landing infrastructure, must be ensured. For this, and considering the prevailing wind direction, based on the data from the previous 30 years, a runway can be defined. This information is compiled through a wind rose, as in Figure 48.

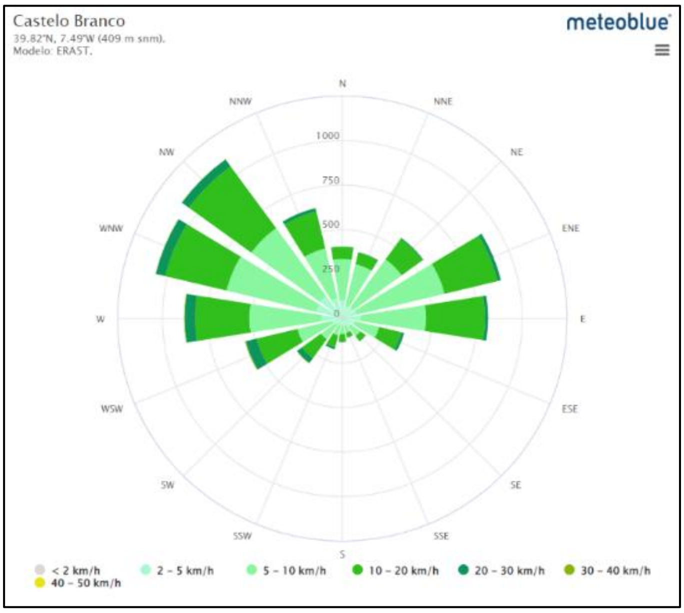

Figure 48 - Castelo Branco region wind rose [94].

Regarding environmental conditions, the prevailing wind direction is NW-SE, with the windspeed averaging from 2 km/h to 30 km/h (1 knot to 16 knots). In spite of this, it is clear that a speed of 5 km/h to 10 km/h (2.7 knots to 5.4 knots) is most frequent, making this dam a suitable location for the implementation of a water landing infrastructure, in this direction.

4.3.1.2. Off-shore facilities

For this water landing infrastructure, regarding off-shore facilities, a runway with a safety area and turning basins was designed, as well as marking buoys, radio activated beacons and anchorage areas. For the runway, the direction of NW-SE was chosen for proper alignment with the prevailing wind of the region. For the proposed infrastructure, its placement is as in Figure 49 and the overall dimensions are as in Table 9.

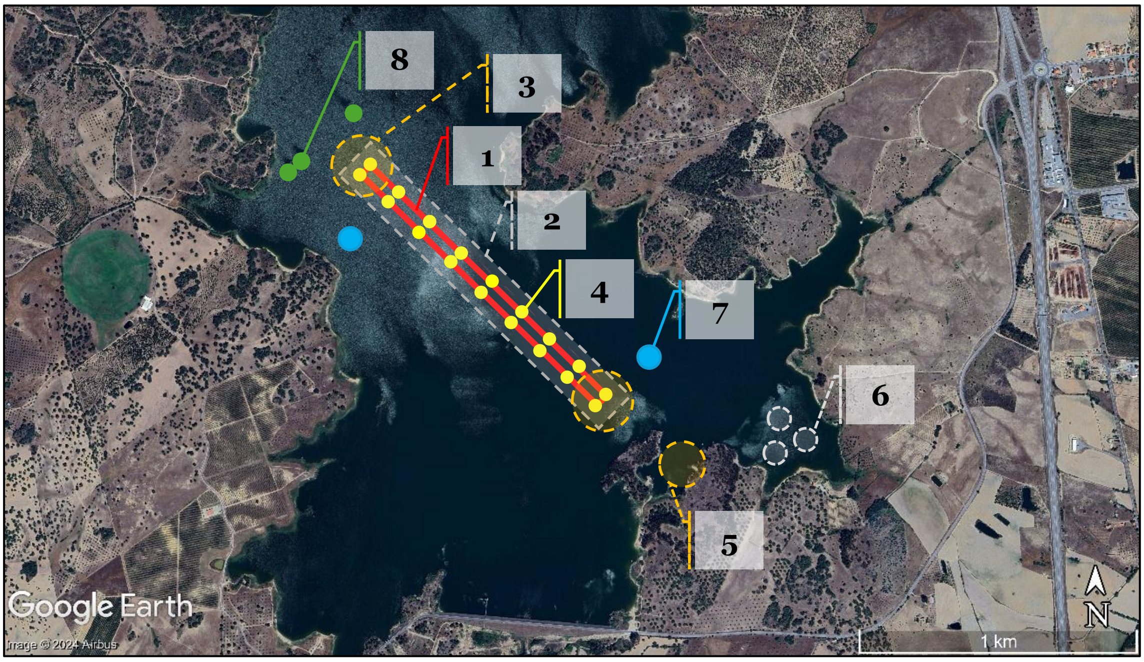

Figure 49 - Marateca Dam Off-shore proposed facilities. Image retrieved from Google Earth.

Table 9 - Marateca Dam Off-Shore facilities dimensions.

Number[11]	**Off-Shore Facilities**	**Length**		**Width**		**Diameter**	
		Feet	**Metres**	**Feet**	**Metres**	**Feet**	**Metres**
1	Runway NW-SE	3937	1200	197	60	N/A	
2	Runway Safety Area	4593	1400	393	120	N/A	
3	Turning Basins	N/A	N/A	N/A	N/A	427	130
5	Turning Basin (for shoreline facilities use)	N/A	N/A	N/A	N/A	328	100
6	Anchorage Areas	N/A	N/A	N/A	N/A	246	75

The proposed length and width of the runway, safety area and the turning basins on the runway ends, were chosen so that the standards needed for the operation of the chosen aircraft (Cessna 208 Grand Caravan EX) are met. The turning basin located near the shore (number 5 on the Figure 49) was placed so that aircraft could manoeuvre in the most convenient way possible to enter the shoreline facilities, mentioned in the next subchapter – **4.3.1.3 Shoreline Facilities**.

[11] The numbers on Table 9 first column are referred to the infrastructures proposed and identified on Figure 49. Number 7 refers to a radio-activated beacon and Number 8 to visual markers for obstacles. Both do not have established dimensions.

In addition to the mentioned infrastructure, visual aids should be established. For this purpose, lighted buoys (number 4 on the Figure 49) are set to be placed at an even distance of 49 ft (15 m). They should ensure that they are visible from at least 1000 feet (300 metres). Additionally, since no maritime or traffic regulations apply to this dam, visual markers should also be placed on both ends of the runway. For the purpose of advising marine traffic or recreational activities that an aircraft is incoming, Radio-activated beacons (number 7 on the Figure 49), are needed. As such 2 of them were placed in opposite sides of the runway for better visualization. For the purpose of denoting obstacles, International Orange (with white stripes) painted visual markers (number 8 on the Figure 49) should be placed, as well.

For additional aircraft parking areas, 3 anchorage locations (number 6 on the Figure 49) could be placed. These anchorage locations have a designed diameter of 60 metres to account for aircraft drift due to the wind influence. The location for this purpose was chosen due to the natural characteristics of the vicinity coast, that can provide separation from the remaining operational areas of the Dam.

4.3.1.3. Shoreline facilities

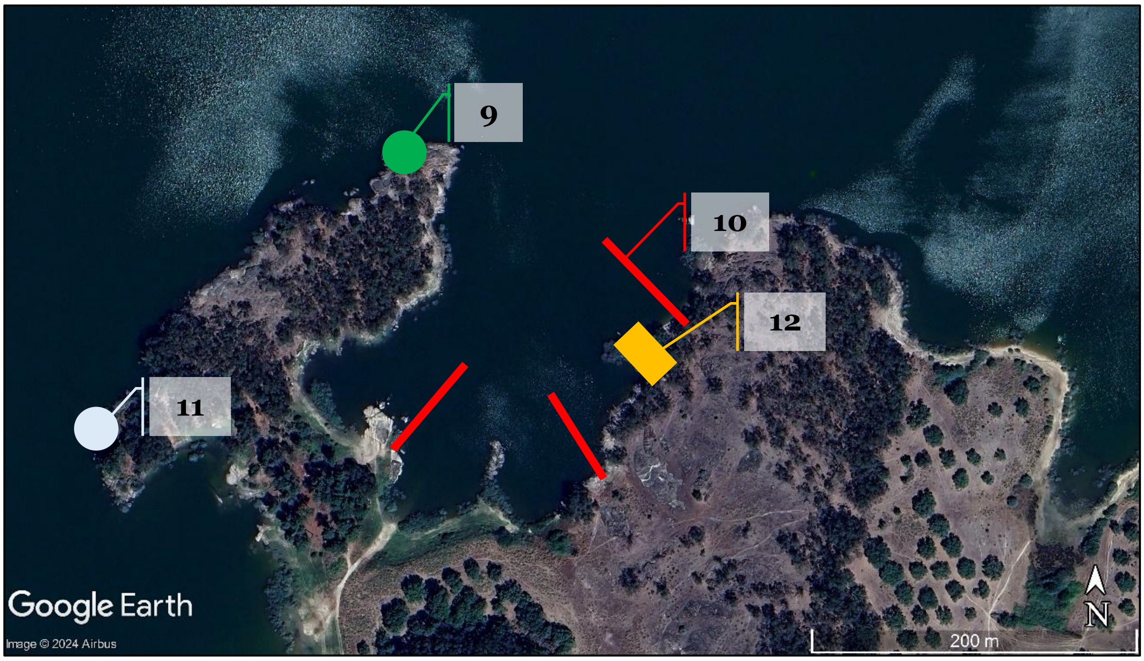

Figure 50 - Marateca Dam proposed Shoreline facilities. Image retrieved from Google Earth.

Shoreline facilities are presented in Figure 50. For these, the proposed infrastructure will rely on 3 separate docks (number 10 on the Figure 50) equipped with both bull rails (painted in International Orange with white stripes) for proper aircraft securement, and with car tires as a fender system. This ensures that the aircraft will not be damaged by the collision with the docks provoked by environmental conditions.

The docks will have a length of 60 metres, being able to accommodate 3 aircraft (considering the proposed aircraft) with a regular spacing of approximately 8 metres in between to ensure a safe distance between them. With this, the infrastructure will be able to dock 9 aircraft at the same time, into the water. As a fire hazard mitigation measure, they should be equipped with suitable places for the instalment of at least one fire extinguisher per aircraft. It is important to mark the docks with proper signs (mentioned in Chapter 2) for both pilot identification, and for denoting a restricted people access area. In the docks, the placement of emergency operation lifeboats should be assessed, to aid aircraft in distress on this infrastructure.

It was placed, as a form of visual aid for pilots, a truncated cone shaped wind direction marker (number 9 on the Figure 50) and it should be painted in international orange with white stripes for better visualization (at least 1000 feet or 300 metres). Furthermore, a water landing infrastructure identification light (number 11 on the Figure 50) was placed to assist the identification process in the operation.

To enable aircraft to exit the water and access on-shore facilities, a 23 metres long and 12 metres wide ramp (number 12 on Figure 50) was aligned with prevailing winds to reduce manoeuvring in harsh conditions. Its slope was limited to a 6:1 ratio.

4.3.1.4. On-shore facilities

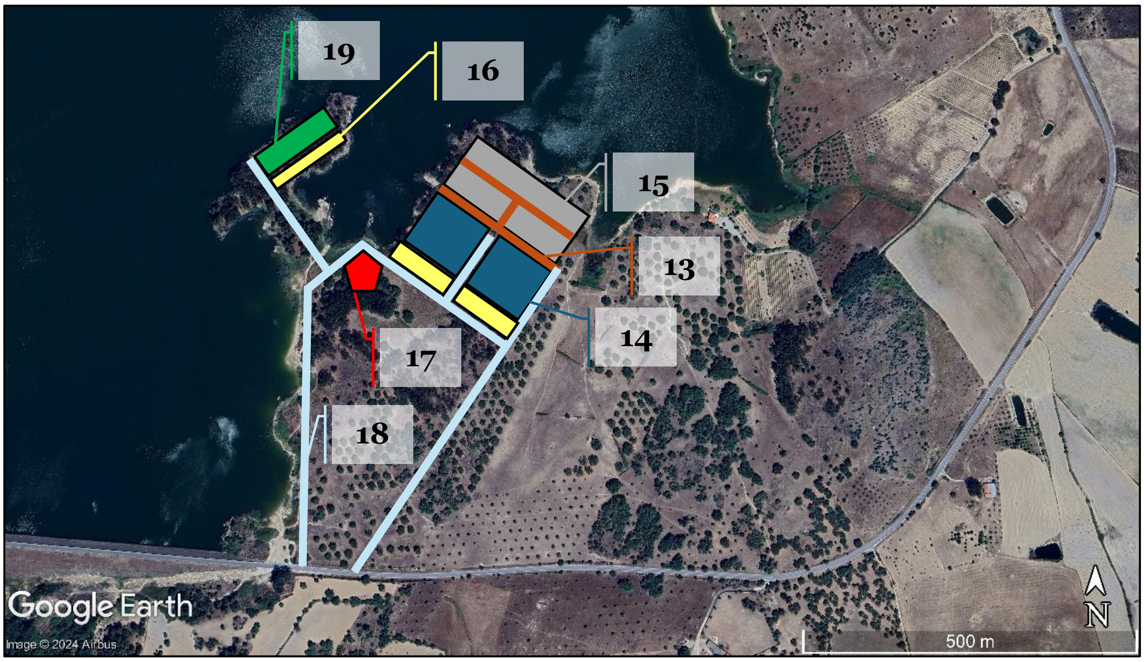

Figure 51 - Marateca Dam proposed On-shore facilities. Image retrieved from Google Earth.

For proper support of the water landing infrastructure operation, on-shore facilities must be set. For this purpose, multiple facilities were designed to not only suit the needs of the airman but also for non-airman people to take advantage of. These are visually represented on Figure 51.

For the airside of the infrastructure, a lighted taxiway (number 13 on the Figure 51) is proposed so that pilots can exit the water through the designated ramp (number 12 on the Figure 51), into the 2 available hangars (number 14 on the Figure 51), or the available apron (number 15 on the Figure 51). The taxiways are to have a width of 20 metres to ensure proper aircraft wingtips from the remaining infrastructure. Both proposed hangars should offer space not only for aircraft storage (Proposed dimensions: Length: 75 m; Width: 75 m; Height: 15 m – capable of storing 8 aircraft in total), but also for maintenance practices. The apron (Proposed dimensions: Length: 100 m; Width: 75 m) is proposed to accommodate 10 aircraft, considering that the proper aircraft distance is met. These aprons should be equipped with tiedown solutions for aircraft securement as well as fire extinguishers for fire related emergencies. It is also important to note that for safety and security reasons, the airside must be segregated from the landside through fences, for example. For this purpose, lighting should be installed in every movement area, inside and out of the airside. Furthermore, in order to ensure that wildlife strike hazard mitigation efforts are being carried out, some aircraft dissuasion methods should be implemented, such as bioacoustic loudspeakers.

Regarding the landside, an administrative building (number 17 on the Figure 51) should be constructed so every aspect of the infrastructure management can be defined and maintained. This building, if large enough, could also accommodate rescue and firefighting operations and fuelling services. The first to ensure that the criteria set on Chapter 2 regarding this matter is being complied and the latter for operation support (for example, refuelling cars and tanks).

In order to being able both to receive aircraft operation related people and others, public parking (number 16 on the Figure 51) and well connected through good road accesses (number 18 on the Figure 51) should be implemented. The proposed roads could be wide enough to accommodate two different direction ways, not only for convenience, but also for good emergency response. Additionally, and for tourism purposes, a restaurant, with a sightseeing platform and aviation-related stores (number 19 on the Figure 51) could be implemented in such way that aircraft operation and tourism related activities are not compromised, by both working in synergy. It is important to notice that the A23 motorway is nearby and with good access to the infrastructure.

4.3.2. Aguieira Dam

4.3.2.1. Site Selection

The Aguieira Dam, is a major hydroelectric infrastructure on the Mondego River, located between Coimbra and Viseu municipalities. This dam is at approximately 50 km in straight-line distance from the Viseu Aerodrome [95]. Both the location and a satellite view are represented in Figure 52.

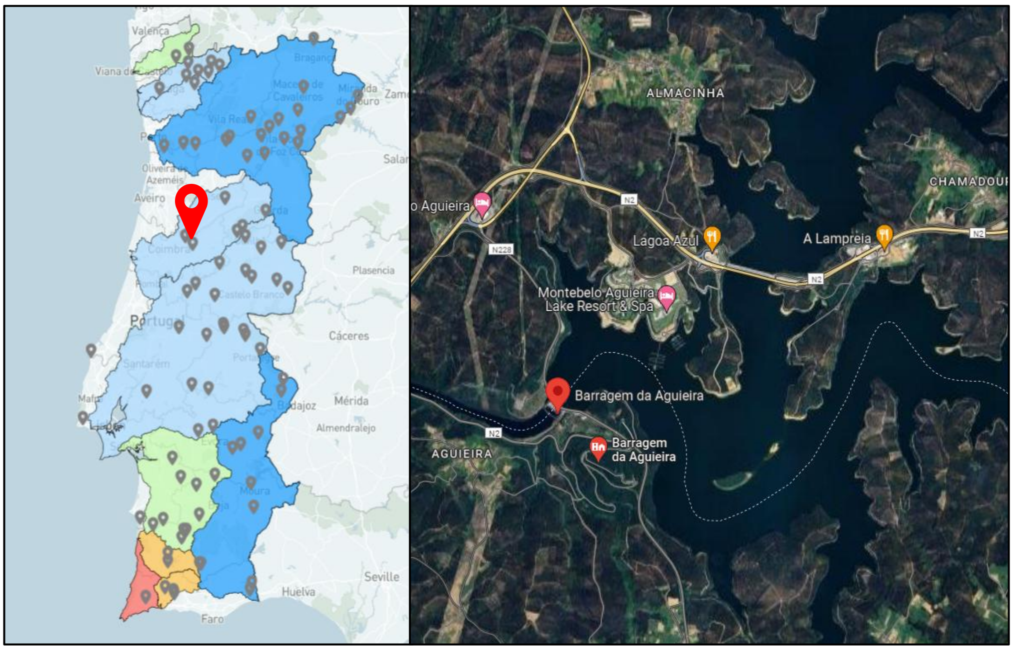

Figure 52 - Aguieira Dam Location (Left) [96] and Satellite view (Right) [97].

This dam was completed in 1979 and inaugurated in 1981 and stands 89 meters high, 400 metres across, making this a substantial infrastructure for its class. It mainly generates electricity and serves as a flood control and water supply for the region as well as irrigation for agricultural fields [98].

This extensive water reservoir is currently used for several recreational activities, such as sailing, rowing, canoeing and water skiing. Also, fishing enthusiasts can discover many secluded spots for their activities. This presents an additional challenge regarding water operations due to the presence of obstacles such as boats on the water. As such, and in the same way as discussed in the previous chapter, steps for hazard mitigation must be ensured in this regard. As an additional fact, when this dam was filled, it submerged several villages, such as Breda and Foz do Dão [95]. Because of this, a study of the bottom obstacles should also be performed when developing and applying the content developed in this Chapter.

The same study of the prevailing winds is also necessary for the reasons already mentioned. As so, as based on the available 30-year data, presented in the form of a rose wind on Figure 53, the runway and the adjacent areas can be established. In this dam, the prevailing winds have the direction of E-W, with windspeeds of 2 km/h to 30km/h (1 knot to 30 knots).

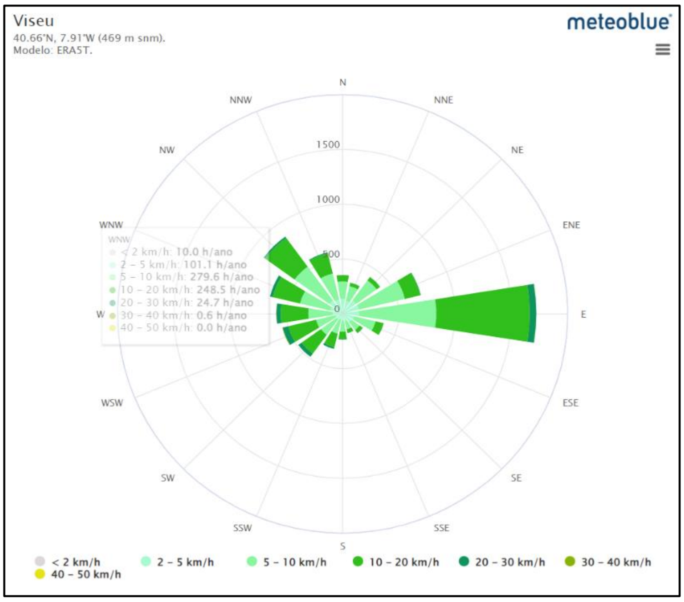

Figure 53 - Viseu region wind rose [99].

In spite of this being the prevailing wind, due to the dam physical characteristics, the infrastructure alignment must be changed. As such, the second most prevailing wind figures are to be considered, with the direction of WNW-ESE and speed of 2 km/h to 20 km/h (1 knot to 11 knots). By choosing to propose the runway in this direction, additional operational challenges arise, such as landing/taking-off during crosswind conditions. That's why it is important to ensure a proper support infrastructure to aid pilots to operate safely under these conditions.

The development of the operational and support infrastructure needs to account for the shoreline characteristics. Since the coastal typology is different from the case studied in the previous Subchapter, being less flat, the infrastructure is more limited. Due to this fact, the land where the necessary support means are proposed to be established, needs to be flattened, resulting in a more onerous development.

4.3.2.2. Off-shore facilities

For this location, the proposed infrastructures in the previous subchapter are also addressed for the same purposes, however, due to its orographic characteristics, the development and construction are more limited.

The water landing runway was aligned with the ANEPC firefighting scooping operations runway of this dam (Figure 3 of this Dissertation) rather than with the prevailing wind, due to the reasons mentioned on the last paragraph. Adjacent areas were implemented with the placement of Figure 54 and with the dimensions presented in Table 10.

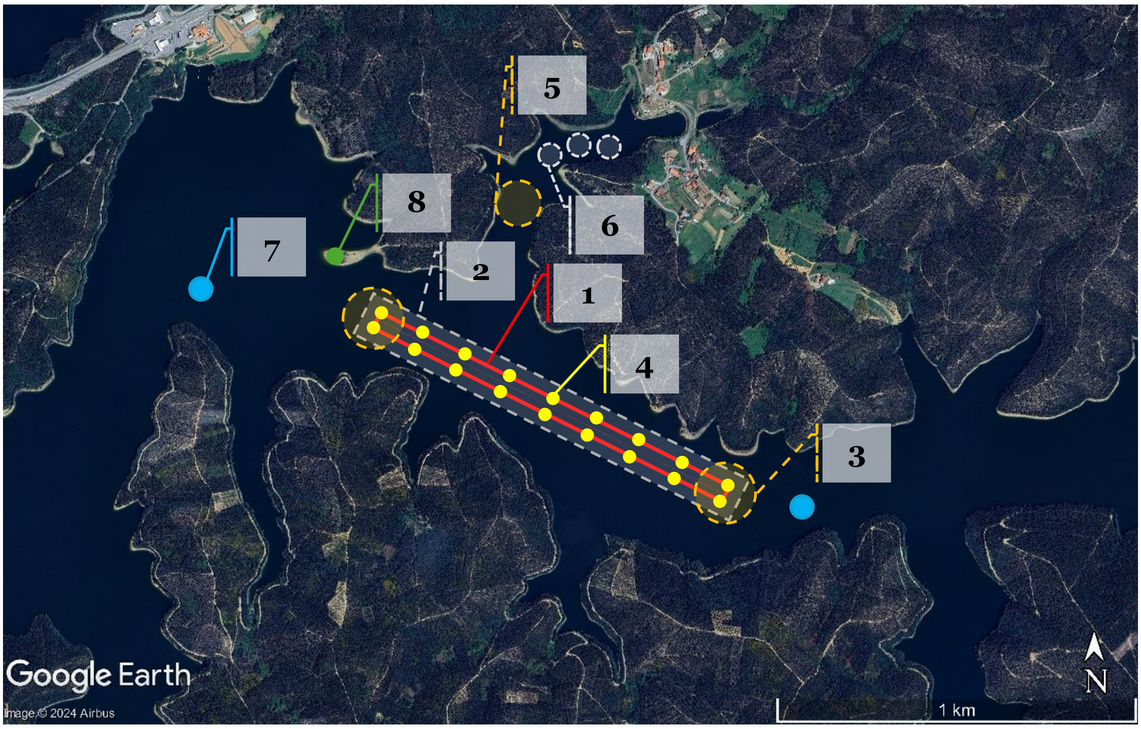

Figure 54 - Aguieira Dam Off-shore proposed facilities. Image retrieved from Google Earth.

Table 10 - Aguieira Dam Off-Shore facilities dimensions.

Number[12]	Off-Shore Facilities	Length		Width		Diameter	
		Feet	Metres	Feet	Metres	Feet	Metres
1	Runway WNW-ESE	3609	1100	197	60	N/A	
2	Runway Safety Area	4593	1400	393	120	N/A	
3	Turning Basins	N/A	N/A	N/A	N/A	427	130
5	Turning Basin (for shoreline facilities use)	N/A	N/A	N/A	N/A	328	100
6	Anchorage Areas	N/A	N/A	N/A	N/A	246	75

[12] The numbers on Table 10 first column are referred to the infrastructures proposed and identified on Figure 54. Number 7 refers to a radio-activated beacon and Number 8 to visual markers for obstacles. Both do not have established dimensions.

The proposed runway is shorter than the one addressed in the previous chapter, however, for the aircraft chosen for the study, it is a suitable one, in dimension terms. In this runway, visual aids are also covered by lighted buoys – distanced approximately 459 ft (140 m) from each other - (number 4 on the Figure 54) to delimit it, as well as radio-activated beacons (number 7 on the Figure 54) and visual markers for the sand bench present at the end of the runway (number 8 on the Figure 54). It's also proposed the implementation of 3 anchorage locations (number 6 on the Figure 54) with 246 ft (75 m) of diameter.

It is important to note that for both entering shoreline facilities or the runway, the latter must be cleared and there must be not any aircraft approaching or departing the proposed infrastructure, for safety purposes.

4.3.2.3. Shoreline facilities

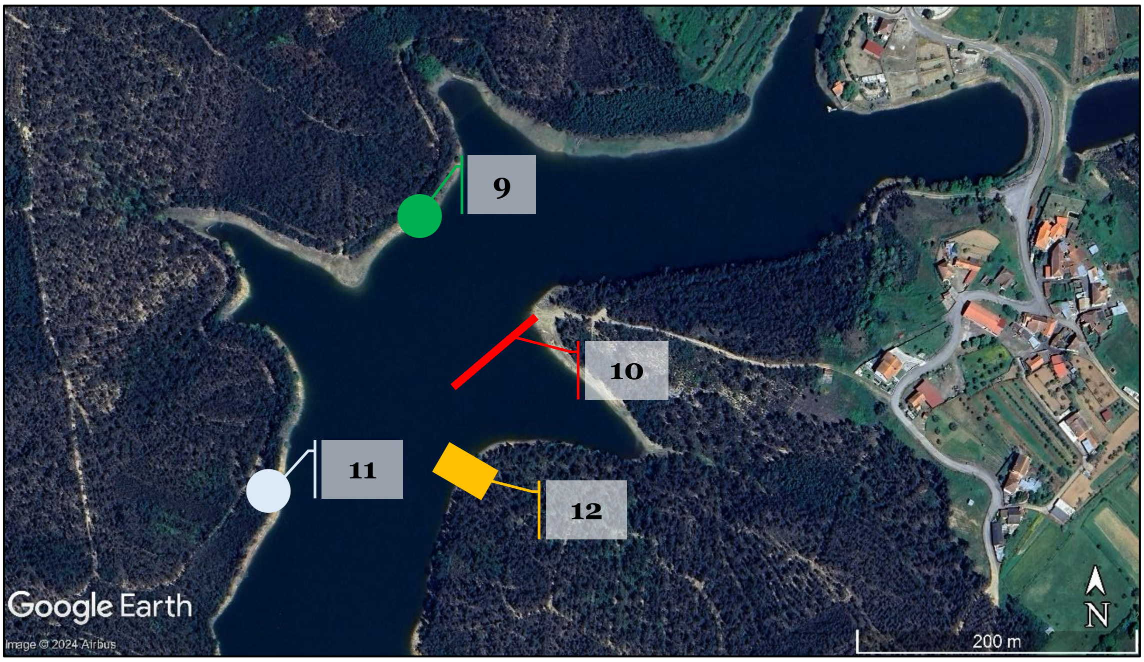

Figure 55 - Aguieira Dam proposed Shoreline facilities. Image retrieved from Google Earth.

The proposed shoreline facilities are presented in Figure 55. For these, a dock (number 10 on Figure 55) with firefighting capabilities, clear identification and signage and with the same characteristics of the ones mentioned in the previous subchapter, must be implemented. This dock will also be able to accommodate 3 aircraft, while ensuring a proper, safe distance between them. Furthermore, it should also accommodate lifeboats for emergency response purposes.

As visual aids for pilots, both a wind direction marker (number 9 on the Figure 55) and an identification light (number 11 on the Figure 55) are also proposed and located in such manner that they are both visible on the air and on the water.

To conclude shoreline facilities, a ramp is necessary. The proposed ramp (number 12 on the Figure 55) for this the purpose of exiting water is marginally smaller than the other proposed on the previous infrastructure. The one proposed in this subchapter has the following dimensions: 20 meters long and 12 meters wide. It is important to reiterate that this ramp should not have a slope greater than a 6:1 ratio.

4.3.2.4. On-shore facilities

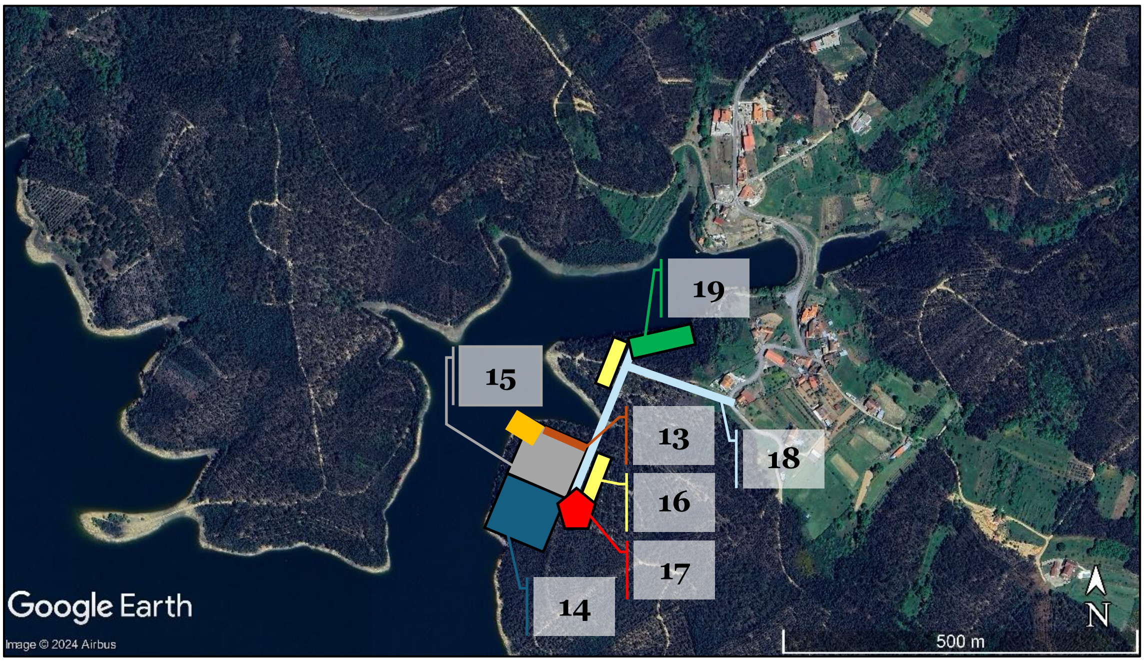

Figure 56 - Aguieira Dam proposed On-shore facilities. Image retrieved from Google Earth.

Figure 56 presents the placement of the proposed on-shore facilities. For these, it is proposed a lighted taxiway (number 13 on the Figure 56) for clearing the water onto the available hangar (number 14 on the Figure 56) and apron (number 15 on the Figure 56), 20 meters wide to ensure proper aircraft wingtip clearance. As was the case for the previous Dam study, also this hangar (Proposed dimensions: Length: 50 m; Width: 50 m; Height: 15 m) can be used for maintenance purposes and store up to 4 aircraft whereas the apron (Proposed dimensions: Length: 50 m; Width: 50 m), could store up to 3 aircraft. For the latter, firefighting and tiedown capabilities shall be offered.

Since security standards must be met, also in this proposal, fences shall be constructed and movement areas lighted. This prevents unwanted movement on the airside, that could compromise safe operations. Furthermore, and since the area has a dense vegetation with several forms of wildlife, also here strike hazard mitigation efforts should be put in place.

Parking spaces (number 16 on the Figure 56) are also proposed, as well as an administrative building (number 17 on the Figure 56), that shall be equipped with a firefighting department as well as fuelling services.

Also, a road connection is necessary. By considering that the ground must me levelled, it is important to consider that there is the possibility that the proposed roads (number 18 on the Figure 56) could not be constructed in the way that is shown on the mentioned Figure. Additionally, and for tourism purposes, a restaurant/sightseeing facility (number 19 on the Figure 56) could be implemented. Even though it is not a necessary infrastructure, it could ramp up the affluence and raise interest of the operations. For general access, the route N2 is close by, offering a viable access to the infrastructure.

Since all of the necessary infrastructures for the correct implementation of water landing infrastructures was already discussed, in the next Subchapter, a general guide for operating at them will be assessed. This guide will focus on the several parts that constitute a full flight operation, focusing on the water landing and taking-off aspects.

4.4. Training guides to operate at Water Landing sites

As any other aircraft operation, also while operating in water landing sites, it is still necessary to make considerations regarding the different flight phases. This subchapter aims to provide a guide for operation assessment for the most critical phases, that should be addressed when pilots are trained to make use of the proposed infrastructure.

The different mission flight stages are the following:

1. **Pre-flight;**
2. **Take-off;**
3. **In-flight;**
4. **Landing;**
5. **Post-Flight.**

Each flight stage comprises different, but important procedures, that should be clearly outlined for a successful mission. Regarding the proposed infrastructure, the most critical phases are the pre-flight for preparing the mission and perform risk assessment considerations as well as the emergency procedures discussion, take-off and landing.

Even though it is not a critical stage, the post-landing procedures are also important to flight crews be able to take advantage of the support facilities.

4.4.1. Pre-flight Procedures

The stage that precedes the flight one comprises some important aspects that ensure the operation is relatively safe and shall not be neglected. At this stage it is important to perform an operation risk assessment, fuel and weight calculations based on the planned mission, altitude density and related environmental conditions. A safety aborting point located on the runway shall also be defined. Furthermore, an aircraft pre-flight inspection, based on a checklist shall be conducted.

While most of the mentioned pre-flight procedures can be found on the relative Aircraft's Pilot's Operating Handbook (POH), the risk assessment shall be relative to the operational intricacies of the planned mission. It is important that the risk assessment is based on a proven model such as the one presented in the Figure 43 of this Dissertation. Therefore, the risk assessment proposed to be utilized on water landing infrastructures could comprise, but are not limited to the hazards and mitigation measures for each critical flight stage (considering a water landing infrastructure on a dam), presented on **Appendix B**.

For the mentioned aircraft model on this Chapter, the Pre-flight inspection covers all areas of the aircraft. Since it is a vast list of topics to consider in this inspection under defined zones, only the zones to be checked will be presented in Figure 57.

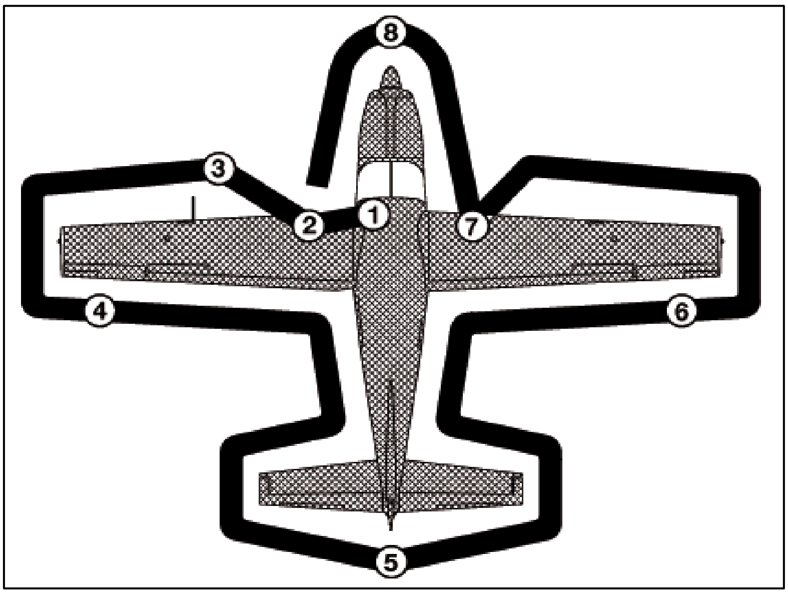

Figure 57 - Cessna 208 Grand Caravan Pre-flight inspection zones [100].

According to the POH of this aircraft [100], the zones that are needed to be inspected are the following:

1. Cabin;
2. Left Side;
3. Left Side Leading Edge;
4. Left Wing Trailing Edge;
5. Empennage;
6. Right Wing Trailing Edge;
7. Right Wing Leading Edge;
8. Nose.

While inspecting the aircraft, and since they operate in water environments, it's also important to address corrosion spots and condition of aircraft paint protection. Failing to perform this assessment can result in fragilized aircraft structures that can compromise the overall safety of the flight. If the aircraft is operating in salt-water conditions, one should wash the aircraft with fresh water, if available, to minimize corrosion effects.

A more detailed pre-flight inspection checklist specific to this aircraft, can be found in its POH [100], that should be placed in such manner that is always accessible to the flight crew at any moment of the mission.

By performing a mission briefing, as well as a detailed risk assessment and an assessment of emergency procedures to account for during the mission, the overall aircraft physical inspection can take place. With all these steps accounted for, the mission can begin.

4.4.2. Take-off Procedures

For this flight stage, pilots should assess the aircraft configuration in accordance with each aircraft POH. The general considerations to account for when taking-off are the following [100]:

1. Wing Flap setting;
2. Power lever setting;
3. Rotate speed;
4. Advised airborne speed;
5. Wing Flap retraction speed.

During this phase, the aircraft transitions from displacement to planning position. The Drag resistance is significant on the first stage however, as the aircraft speed increases, this component is reduced since the aircraft only touches the water on the floats' step, reducing the contact area [60]. Figure 58 visually represents the Drag component in function with the speed of the aircraft.

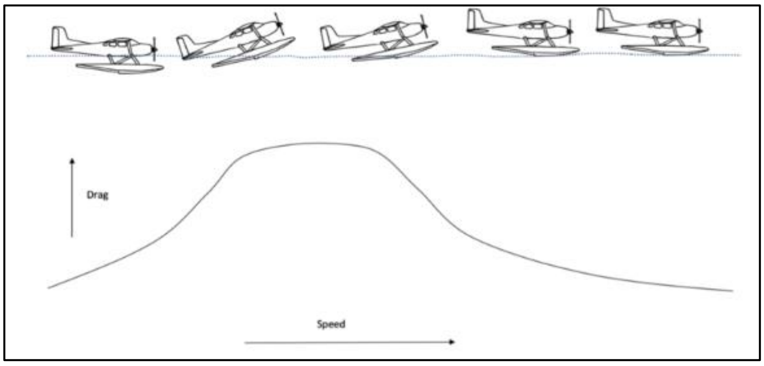

Figure 58 - Aircraft Drag component in function with the speed [60].

When taking-off, some considerations regarding currents need to be assessed. In spite of studying Dam cases in this dissertation, sometimes currents are developed due to wind presence. To assess this case, the following considerations regarding the wind/current relation should be met when taking-off:

1. **No wind:** take-offs/landing shall be made with the developed current;
2. **Opposite directions:** take-offs and landings shall be made into the wind and into the current;
3. **Same direction:** pilot's decision. Generally, if this is the case, if the wind is considered to be stronger than the current, take-offs and landings shall be made into the wind. If the opposite case is verified, vice-versa.

Since the water runways that are proposed in the previous subchapter have well-defined directions, the considerations made before shall be subject to the pre-flight risk assessment to not make the mission harder to execute and in extreme cases, making it unsafe. Note that these considerations are also valid for open-water operations [60]:

- For crosswind take-offs, flight crews should consider that aircraft tend to weathervane into the wind as it gains speed. On an initial stage, it is advised for pilots to let the aircraft vane until it is on its steps. When this condition is met, the aircraft's flight surfaces gained effectivity, allowing the pilot to control the take-off with both aileron and rudder inputs. Furthermore, a clean-wing configuration, with FLAPS UP can improve directional control, but also increases the take-off distance;
- For rough water take-offs, the power input shall be made when the aircraft is at the bottom of the wave. It is normal that in this condition, the aircraft's attitude

is slightly higher, and this behaviour should be maintained in such way that the float bows do not dig into the wave. On the other side, this attitude shall not be excessively high since the drag force will be increased exponentially, increasing also the take-off run. This procedure is depicted in Figure 59;

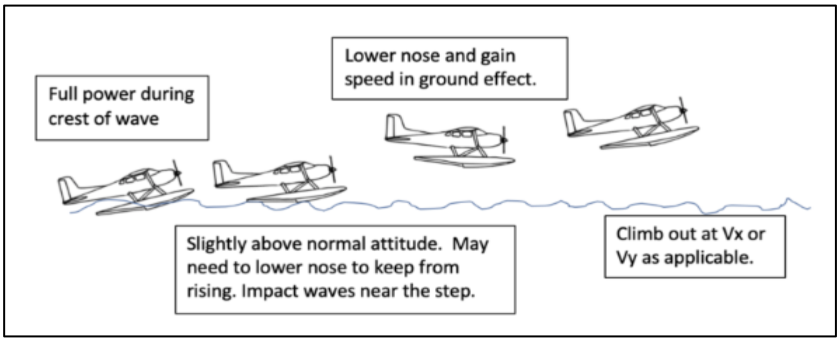

Figure 59 - Rough waters take-off technique [60].

- For glassy water conditions, since the water reference is difficult to assess after airborne, pilots should ensure a positive rate of climb, minimizing an inadvertent descent and subsequent water contact. Avoiding turns should also be prevented to distance the wingtip as much as possible from the water;
- In case of a confined area situation, pilots shall gain as much altitude as possible in as short distance as possible. For this case, a curved path technique shall be adopted with the definition of an abort point. In order for this complex manoeuvre to be feasible, calm wind conditions are required. *"This procedure was removed from the FAA requirements, as some students were performing the manoeuvre in other than calm conditions"*.

Furthermore, another important aspect to cover as the aircraft approaches the runway with a take-off intention, is an obstacle and debris identification to ensure a safe, smooth operation.

4.4.3. Landing Procedures

As mentioned in previous Subchapters, the most critical stage of this kind of mission is the landing one. The most important aspects to consider when performing this manoeuvre are the following [100]:

1. Seats, Seat belts and Shoulder Harnesses securement;
2. Fuel tank selector configuration;
3. Propeller RPM lever;
4. Wing flaps configuration;
5. Advised landing speed;

6. Touchdown aircraft attitude;
7. Power lever setting.

Since Water Landing procedures were thoroughly addressed in subchapter **2.5 – Water landing Procedures**, only the topics to cover when pilot training will be outlined down below:

1. Reconnaissance – Five W's Mnemonic, for example, discussed in Chapter 2;
2. Normal Take-off/landing;
3. Crosswind landing;
4. Downwind landing;
5. Glassy water landing;
6. Rough water landing;
7. Confined area landing;
8. Go-around and emergency landing.

4.4.4. Post-flight Procedures

After landing there are also considerations that are necessary to the successful mission completion. Right after landing, the aircraft shall have a configuration that allows for taxiing and for clear identification by other infrastructure users. For most aircraft, the POH recommend that the Flaps are retracted and the Strobe lights on.

During taxi operation, pilots need to navigate carefully around obstacles, ensuring a proper aircraft distance to the coast to avoid hitting it and also beaching on shallower waters, as in Figure 60. Additionally, since this kind of aircraft has the tendency to weathervane as it was addressed in previous chapters, this tendency has to be accounted for when in route to the dock or mooring facilities. For example, on the Figure 40, it is possible to note that in that case, the pilot left a greater clearance to the obstacle located on the left-hand side since the prevailing wind comes from that direction.

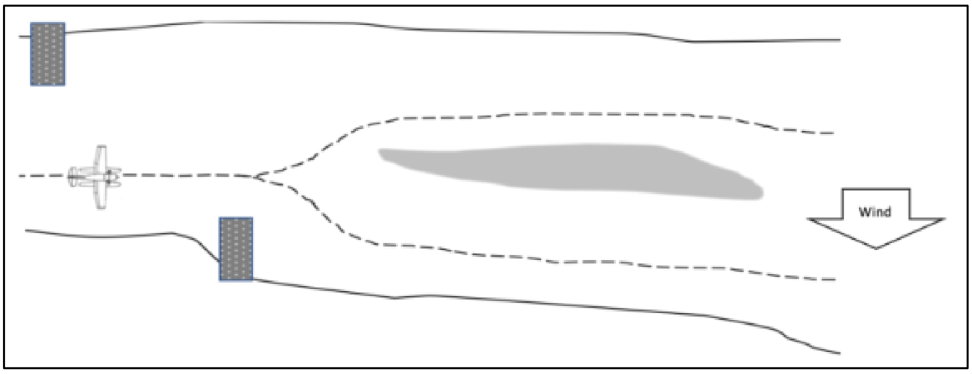

Figure 60 - Taxiing with present obstacles considerations [100].

After taxiing to the desired aircraft securement location, the considerations regarding anchoring, mooring, docking, beaching and ramping shall be the ones addressed in a detailed manner on Subchapter **2.5.12 – Postflight Procedures**.

For the proposed infrastructures, the considered critical postflight procedures are the following:

4.4.4.1. Anchoring

In the case of making use of the proposed aircraft anchoring locations, one must note that this is only a solution for aircraft storing during light-wind conditions and for short amounts of time. The line that attaches the anchor to the aircraft should be around 7 times the depth of the water and it should be attached to the mooring cleats available on the floats. The engine should be turned off when throwing the anchor. By watching reference points on the shore, the aircraft is anchored when drifting has stopped.

4.4.4.2. Docking

While performing the docking manoeuvre, pilots should not only turn off the aircraft engine in order to coast to the desired location at low speeds but also make advantage of the aircraft weathervane characteristics to sail into the desired location. Additionally, there are other factors to account for:

1. Turn off the aircraft magnetos: a deckhand may accidentally turn the propeller while handling it, starting the engine accidentally if the magnetos are turned on;
2. If a strong wind is blowing towards the dock, it will be easiest to sail rewards to the dock;
3. In case of human-assistance on the dock, it is necessary to brief the helper to avoid moving in front of the aircraft's strut to prevent propeller accidents;
4. Docking nose-first should be avoided since the nose landing gear is fragile, additionally, when departing, sharp turns shall be prevented to avoid hitting the dock with the tail.

Two illustrative examples of aircraft docking are depicted in Figure 61.

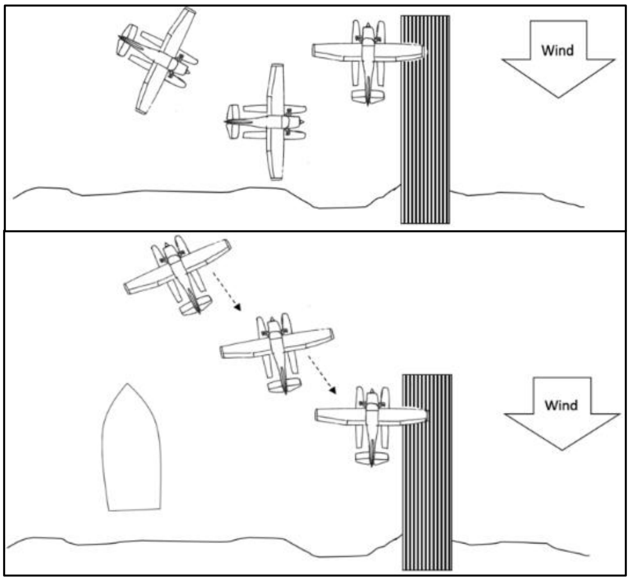

Figure 61 - Examples of aircraft docking techniques [60].

4.4.4.3. Ramping

A smooth, controlled approach to the ramp should be planned to avoid accidents and damages. As so, if the wind reveals to be parallel to the ramp, it is beast to approach it downwind, allowing the weathervane characteristics of the aircraft to assist in the turn to the ramp. To ramp, the pilots should:

1. Add power when nearing the ramp to create a bow wave that cushions the floats upon contact;
2. Exercising caution when stepping onto the ramp, as it can be slippery;
3. Avoid using concrete ramps with aircraft on straight floats as it was discussed on subchapter **2.5.12.5 – Ramping**;
4. Ensure proper landing gear configuration – extended - when taxiing onto a ramp, as it can take some time to deploy. Additional caution is advised since brakes may be initially ineffective when exiting the water;
5. The aircraft shall be aligned with the ramp and turns shall be avoided while ascending it. The use of FULL FLAPS configuration in addition to forward elevator pressure may help to counteract the nose up tendency when accelerating in the ramp;
6. The aircraft shall be taxied slowly down ramps, and changes in ramp angle shall be noted to avoid getting stuck since in most amphibian aircraft, the floats-ground clearance can be reduced;

7. In the presence of spectators, safety personnel mobilization shall occur since onlookers could not be aware of the dangers of a rotating propeller and that the flight crew has limited visibility.

As discussed previously, also in the Raping procedure, the weathervane aircraft characteristic shall be used in pilot's advantage. On Figure 62, on the left side example image, the aircraft shall be taxied straight into the ramp. On the same Figure, but on the example to the right side, when exiting the ramp, and if turning the aircraft prior to this is unfeasible, the aircraft should be pushed off to the right with rudder inputs, to avoid hitting the shore.

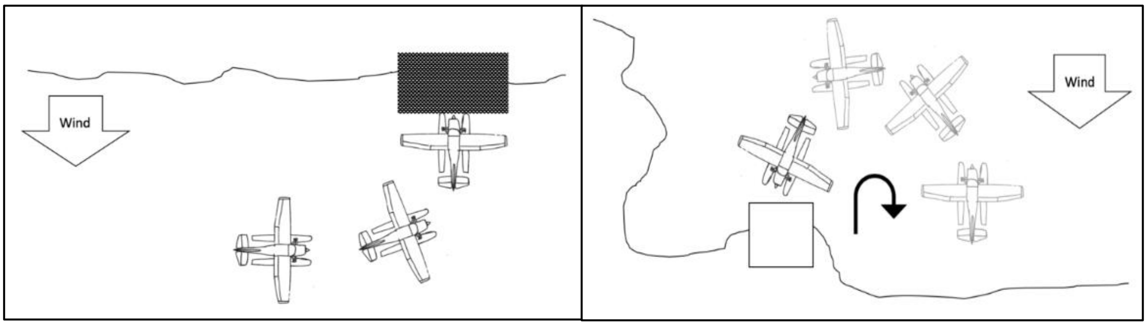

Figure 62 - Examples of aircraft ramping procedures [60].

4.4.4.4. General Visual Inspection

After all postflight procedures are completed and with the aircraft properly secured to the tiedown solutions provided, a general visual inspection of the overall condition of the aircraft shall be made. If any signs of damage are found, a reporting sheet may be filled out to advise other aircraft users of the damage and, if the damages are considered to be substantial, an unscheduled maintenance should be conducted to ensure the aircraft's overall safety.

4.4.5. Emergency procedures

As every aircraft operation is not risk free, also amphibian missions comprise a certain level or risk that can be reduced by providing a proper level of training and preparedness. There are some important cases to be outlined regarding emergency manoeuvres, to aware flight crews of the risks involved. Some of the specific situations to cover are mentioned down below:

1. <u>Submerged Float:</u> On take-off/landings, power must be reduced, and the aircraft must be turned towards the submerged float to slow it down;
2. <u>Night Landings:</u> Due to the lack of visual references on the water, night landings shall be avoided. They should only be considered in an emergency event or if the

water runway is properly lighted with the aid of buoys. In case of a night emergency, nearby airports should also be considered for a land landing. In the case of no other alternative, the glassy water landing technique exposed on subchapter - **2.5.7. Glassy Water Landing**;

3. Crash/Water Damage: According to the Regulation (EU) No 965/2012 [23], the aircraft must be equipped with one life-jacket per person in a readily accessible location from the seat when operating flight over water, as it was discussed in subchapter **3.4.2 – Regulation (EU) No 965/2012**. The life-jacket shall not be inflated until outside the aircraft in order to avoid trapped passengers or flight crews. In the likely event of tipping the aircraft over, the probability of being disoriented is high and, as such, a technique to perceive which way one is facing, is to look at the air bubbles, since they rise to the top;
4. Emergency Egress: In the event of needing to egress the aircraft, the air bubble techniques may be used but also the seatbelt release shall not occur before one perceives the exit path correctly, to avoid floating in the cabin. Since this can be an extreme stressful situation that requires calm and perseverance, pilots should undergo egress training;
5. Disabled Aircraft: Before commencing the flight mission, one should account for the different emergency radio frequencies to contact in the event of a disabled aircraft. This can minimize the assistance time, preventing also traffic collisions, for example;
6. Amphibian Aircraft related items: Pilots shall practise and be trained for the previous topics discussed. Additionally, the aircraft POH manual should be followed to ensure the safest landing possible. If the condition or configuration of the lang gear is unknown, landing on a towered runway can aid in identifying the conditions mentioned and aid in the subsequent procedures to account for;
7. Assess Risks on Preflight: All of the topics above shall be considered when performing the preflight briefing to ensure that all of the flight crew is aware of the risks and that they are the most possibly prepared for an emergency event.

These emergency procedures can be assessed not only on amphibian aircraft training environment, but also for regular flight school training. By providing instructor and student pilots with the proper training regarding water landing, ditching at a well emergency equipped infrastructure could be perceived as a viable alternative for aircraft in distress.

4.5. Chapter Conclusion

In this Chapter, two different water landing infrastructures were proposed, as well as the necessary dedicated support facilities. These were also proposed to address the current lack of such facilities in Portugal. By considering safety considerations, regulatory compliance and operational effectiveness, the proposed designs can be positioned as a valuable asset for aircraft operations in this context. For the correct implementation of the mentioned infrastructures, illustrative diagrams were outlined as well as particular characteristics of the equipment. Considerations regarding limitations of the chosen locations were also addressed. Even though the study was limited to 2 dams, the contend developed in this Chapter provides an idea of the necessary infrastructure and equipment necessary to develop similar facilities in other enclosed spaces. Furthermore, by providing these infrastructures with emergency response capabilities, they could not only support regular amphibian aircraft operation but also offer critical emergency options for non-amphibian aircraft in distress.

Training/Procedural considerations were also exposed, with the aim of providing pilots an insight of the requirements that they should master operate at the proposed infrastructures in a safe and efficient manner. As it was exposed on Chapter 3, and according to the applicable SEP/Sea Class Rating and Portuguese regulations, a theoretical and practical instruction programme shall be implemented with the topics approached in this Chapter, that should also consider the topics exposed in this Chapter.

This initiative is, therefore, a step forward in enhancing aviation safety in the region, providing the possibility for controlled, well-equipped environments and infrastructures for water landings, thereby reducing ditching related hazards.

5. Chapter 5 – Conclusions

5.1. Introduction

This last chapter brings this Master Dissertation to a close by providing a synthesis of its key aspects, reflection and overall conclusions. This chapter also addresses the limitations and difficulties encountered during the research and development process. Furthermore, potential improvements in future work related to the matter developed are also offered.

5.2. Dissertation Synthesis

This Master Dissertation is defined by 5 distinct chapters. They are the following: Introduction, Literature Review, Regulations for Water Landing Infrastructures and Water Landing Training, Case Study and Conclusions.

On the first Chapter, the main objectives of this Dissertation were outlined, as well as the methodology used for reaching them. These were the design of water landing infrastructures at 2 Portuguese Dams and the development of a new training guide for water landing on fixed-wing aircraft.

On this Dissertation, both objectives were achieved. Two Water Landing Infrastructure designs were proposed as well as a guide for water landing training/procedures. In order to carry out the study, both international and local regulations were addressed and considered. By addressing them as a general guidance material, the proposed matter could be implemented in other locations, with different operational realities. Furthermore, the content developed could also be used and applied in critical emergency situations, such as an in-flight engine shutdown.

The second Chapter, the Literature Review, highlights several aircraft accidents that have occurred in Portugal, related to water landings (ditching events) and reveals the lack of emergency infrastructure in Portugal to support pilots during such situations. This Chapter emphasizes that for the events mentioned, the Search and Rescue efforts relied heavily on the presence of nearby people and that a correct assessment of water conditions, obstacles, bird hazards, for example, are crucial to safe operations. Additionally, this Chapter reinforces the need for new, standardized training guidelines for amphibious aircraft operators, that could be tailored to satisfy the operators different operational contexts. Portugal could also take advantage of these infrastructure improvements by examining how other countries address this matter.

The third Chapter, Regulations for Water Landing Infrastructures and Water Landing Training, focuses on the applicable regulations for the development of such infrastructure, as well as the necessary related pilot training. This Chapter identifies gaps in these regulations, in both ICAO and EASA standards, as it was reported by Member States on Assembly meetings. As such, this Chapter aimed to research existing guidelines, developed by international and some local aeronautical authorities, with the aim of extrapolating them to potential guidelines for Portugal. To what concerns the specific training for the operation of amphibian aircraft, the European regulations regarding SEP/Sea Class Rating offers a detailed training on what pilots should master when operating in water landing contexts. These regulations were exposed as well as the current Portuguese ones, proving that they are in concordance with each other. This alignment further supports the possibility of developing amphibian aircraft operations and water landing procedures in Portugal.

The fourth chapter, the Case Study, proposes the implementation of water landing infrastructures on two dams. The chosen ones were the Marateca and Aguieira Dams because of their proximity, to Castelo Branco and Viseu regional aerodromes as well as to the University of Beira Interior. The proposed designs consider safety, regulatory compliance, and operational effectiveness, providing valuable support for aircraft operations. This Chapter relies on representative illustrations of the proposed infrastructures and support facilities, by considering the specificities of each location. In spite of the study being limited to two dams, the proposed solutions could serve as models for similar developments in other areas. Furthermore, as it was mentioned, these infrastructures could also be a valuable asset for aircraft in distress, contributing to the overall aviation safety in the region. In order to being able to take advantage of them, pilots shall be trained and also shall perform safety considerations regarding this specific operation that in a first glance may seem similar to the land-based one, but in reality, they are not.

In conclusion, the dissertation identifies gaps in current infrastructure, highlights the importance of tailored training, and proposes feasible designs for future water landing facilities, all aimed at enhancing not only water reservoir applications, but more importantly, the aviation safety in Portugal.

5.3. Concluding Remarks

In this Master Dissertation, two water landing sites are proposed, as well as procedures that pilots need to be trained and to account for when utilizing them. By proposing such infrastructures, the lack of aircraft emergency support systems across Portugal could be improved, by providing pilots with these alternative solutions for distress cases. The research conducted, underlines the importance and the need not only of these sites, but also the tailored training for amphibious aircraft pilots, that could also serve as a guideline for emergencies on non-amphibian aircraft operations.

The proposed infrastructures, although limited to only two locations, can provide for foundations for future developments in other regions. By extrapolating these results with the applicable regulations, these proposals could be modified to serve other realities, laying the groundwork for a safer, more resilient aviation environment in Portugal.

Since the amphibian aircraft operation may seem, at a first glance, similar to land-based one, they can be very different due to the specificities of both aircraft and environmental conditions. The first related to the increased difficulty to land in crosswind conditions, for example, due to the presence of floats that increase the aircraft's lateral area. The latter related to conditions such as glassy water surface, crosswind also, rough water. For this reason, the development of an operation training guide that comprises a risk assessment stage is essential. This also implies that an evaluation of the most recurring hazards should be conducted and an assessment of their severity and likeliness should be conducted.

The combination of well-equipped infrastructure with a good preparation is the recipe for a viable operation, that in the cases proposed not only ensures a safe operation, but also the increase in dam usage that could be an asset for local tourism as well an increased interest of aviation in Portugal.

5.4. Limitations

The lack of content related to Water Landing Infrastructures, mainly in an European context was certainly a limitation to the production of this Dissertation. Therefore, the study had to be based on guidelines produced by other countries that faced this exact issue. Even though it is already being discussed in ICAO Assemblies, at this time there are still no concrete advances in this regard.

The data available in regard to crucial factors such as water dam currents, depth, shoreline height, prevailing winds and present obstacles is sparce and often incomplete. For this reason, the accurate site assessment for water landings in terms of safe approach and landing zones became difficult.

Furthermore, the production of a training template was also a challenge due to the lack of training content available as flight schools do not make their content available. The guide had to be based on available internet content, compared by the existing Sea Class Rating. This could result in an incomplete guide with potential gaps that should be revised, when deemed necessary.

5.5. Prospects for Future Work

Even though the study conducted had a regulatory compliance basis, there were considerations that were not possible to make, given the available timeframe. By considering the limitations presented before, the prospects for future works could be the following:

1. Focus the study on Water Landing Infrastructures on the sea and river contexts, to be able to see the viability of the study in areas with strong currents and waves as well as other than confined ones;
2. Design of an approach diagram, that considers the objects around the proposed facilities;
3. Environmental/Noise/Water impact studies, for understanding the influence of the operation establishment on the surroundings;
4. Development of a Water Aerodrome Emergency Plan (AEP) for both the proposed infrastructures;
5. Economic Impact/Cost-Benefit Analysis studies, for better comprehending if the development of such infrastructures could be translated in economic growth and region development;
6. Analysis of the proposed Risk Assessment/Training guide feasibility along with flight schools, for better understanding their viability or even suggesting improvements for a completer and more comprehensive ones.

Since no other infrastructure of this kind can be found in Portugal, its implementation could be translated in new opportunities, for flight schools, fire-fighting operations or even for recreational purposes. This can all be assessed in future works related to this Master Dissertation.

5.6. Conclusion

One can conclude that this Master Dissertation was successful regarding the achievement of the purposed goals. It has successfully proposed and justify the implementation of two Water Landing Infrastructures at two dams, Marateca and Aguieira Dams near Castelo Branco and Viseu, respectively. From this, it became necessary a training/procedural guide for using them, that comprises the critical flight stages where the available Infrastructure is a crucial factor.

In conclusion, by analysing the accidents related to water landing/ditching that have occurred in the past in Portugal, the need for better pilot preparation as well as proper support infrastructure became evident and that was the reason that motivated this study. Furthermore, it is important to note that the content developed in terms of risk assessment and pilot training could and should be extrapolated for regular land-based operations since the proposed infrastructures could be a crucial asset for aircraft in distress, by providing readily emergency response.

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Appendix A – Experience requirements and prerequisites for the issue of class or type ratings – aeroplanes

Table ApA 1 - FCL.720.A - Experience requirements and prerequisites for the issuance of class or type ratings - aeroplanes [22].

Category	Sub-category	Requirements
1 - Single - Pilot Aeroplanes	Applicants for the initial issue of privileges to operate a single-pilot aeroplane in multi-pilot operations, either when applying for the issue of a class or type rating or when extending the privileges of a class or type rating already held to multi-pilot operation, shall meet the requirements in point (b)(4) and, before starting the relevant training course, point (b)(5).	
	1.1 - Single-Pilot Multi-Engine Aeroplanes	Complete at least 70 hours as PIC in aeroplanes.
	1.2 - High-Performance Non-Complex Aeroplanes	At least 200 hours of total flying experience of which 70 hours as PIC and comply with one of the following: **1.2.1 -** Hold a certificate of satisfactory completion of a theoretical knowledge course at an ATO; **1.2.2 -** Pass the ATPL(A) theoretical exams; **1.2.3 -** Hold an ATPL(A) or CPL(A)/IR with theoretical knowledge credit for ATPL(A).
	1.3 - High-Performance Complex Aeroplanes	Applicants should not only comply with point **1.2** of this table but also with the following: **1.3.1 -** Hold or have held a single- or multi-engine IR(A); **1.3.2 -** For the first type rating, meet point **5** of this table before starting training.
2 - Multi-Pilot Aeroplanes	As a General Requirement for Multi-Pilot Aeroplanes: • At least 70 hours of flight experience as PIC in aeroplanes; • Hold or have held a multi-engine IR(A); • Pass the ATPL(A) theoretical knowledge exams.	
	2.1 -MCC Course (can be combined with the type rating course)	Hold a certificate of satisfactory completion of an MCC course in aeroplanes, or: **2.1.1 -** Equivalent experience in helicopters (at least 100 hours); **2.1.2 -** Multi-pilot operations (at least 500 hours).
	2.2 - Training Course	Complete the training course specified in point FCL.745.A [22] in this regulation, unless they: **2.2.1 -** Completed training and checking in accordance with ORO.FC.220 and ORO.FC.230 of Annex III (Part-ORO) to Reg. (EU) No 965/2012 [23] within the preceding 3 years; **2.2.2 -** Completed training specified in FCL.915(e)(1)(ii). *
3- Other Provisions	**3.1 - Restricted Type Rating**	May be issued for multi-pilot aeroplanes for cruise relief co-pilots above FL200 whenever other two other crew members have a type rating as per point **2** of this table.
	3.2 - Supervised Flight Privileges	Initial type rating privileges may be limited to flight under instructor supervision and these flight hours must be logged and signed by the instructor on the pilots' logbook. **
Additional Notes		* - FCL.745.A Advanced UPRT course – aeroplanes [22] section. ** - This restriction can be lifted once after demonstration of supervised flight hours have been completed.

Appendix B – Risk Assessment Table proposal

Table ApB 1 – Risk Assessment Table proposal

Flight Phase	Hazard Identified	Risk Level	Mitigation measures	Risk Level after Mitigation Measures
Take-off	Obstacles in water	HIGH	Visual inspection and consider delaying take-off.	MEDIUM
	Engine failure	HIGH	Detailed pre-flight checks and identify emergency landing areas.	LOW
			Identification of emergency landing areas.	LOW
	Fuel Contamination	HIGH	Fuel drainage checks.	LOW
	Landing gear not retracted	MEDIUM	Use POH checklist.	LOW
	Crosswind	HIGH	Delay take-off.	LOW
	Poor visibility	MEDIUM	Delay take-off.	LOW
	Electrical wiring hazards (Cables/Posts)	HIGH	Identify and mark electrical hazards in approach paths and ensure proper distances from electrical installations.	MEDIUM
Climb/Flight	Bird Strikes	MEDIUM	Bird control measures.	LOW
	Turbulence	MEDIUM	Plan flight around known turbulent locations.	LOW
			Secure loose items on the cabin.	LOW
			Wear safety belts.	LOW
	Navigation over water	HIGH	Emergency landing checklists.	MEDIUM
			Placement of life-vests in accessible locations for each crew member.	MEDIUM

Table ApB 1 –Risk Assessment Table proposal (Continuation)

Flight Phase	Hazard Identified	Risk Level	Mitigation measures	Risk Level after Mitigation Measures
Approach	Low fuel level	HIGH	Fuel monitoring during flight; ensure a reserve fuel quantity.	LOW
	Unexpected strong winds	HIGH	Use weather forecast updates and adjust speed and aircraft flight attitude.	LOW
	Electrical wiring hazards (Cables/Posts)	HIGH	Identify and mark electrical hazards in approach paths and ensure proper distances from electrical installations.	MEDIUM
Landing	Rough water conditions	HIGH	Water area assessment in approach, prepare for egress if necessary.	MEDIUM
	Glassy water conditions	HIGH	Adjust approach technique (speed, A/C attitude: shallow descent) and practice glassy water landing techniques.	MEDIUM
	Crosswind conditions	HIGH	Adjust approach technique (speed, A/C attitude) and practice crosswind landing techniques.	LOW
	Confined space condition	HIGH	Assess area before approach and practice confined areas landing techniques.	MEDIUM
General	Pilot fatigue	HIGH	Ensure proper rest before flights and monitor crew rotation schedules, if applicable.	LOW
	Pilot experience	HIGH	Regular training and flight simulation training sessions.	LOW