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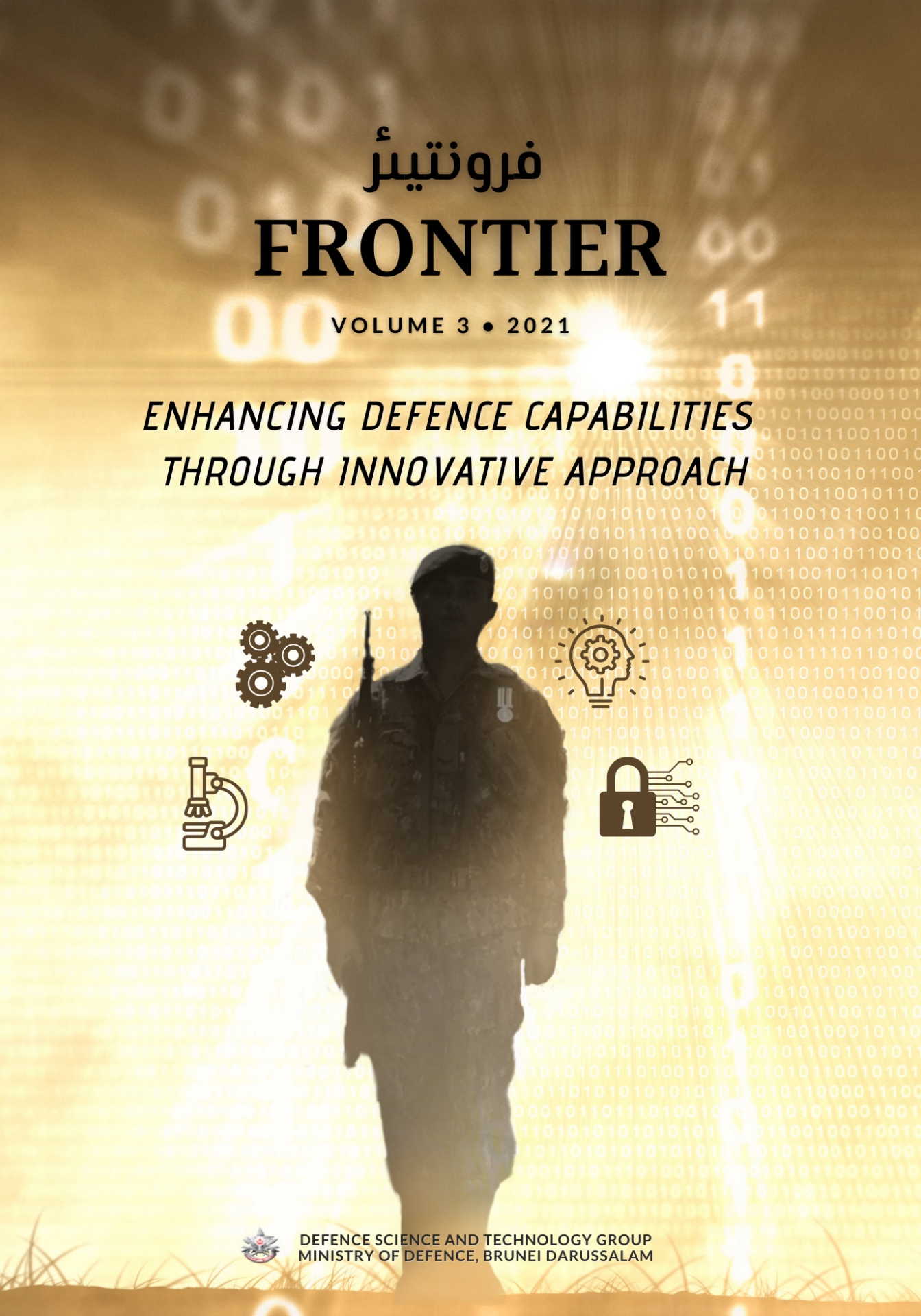
FRONTIER

VOLUME 3 • 2021

ENHANCING DEFENCE CAPABILITIES THROUGH INNOVATIVE APPROACH



DEFENCE SCIENCE AND TECHNOLOGY GROUP
MINISTRY OF DEFENCE, BRUNEI DARUSSALAM

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THE FRONTIER TEAM

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EDITORIAL FOREWORD

Hasrinah binti Matyassin
EDITOR-IN-CHIEF

بسم الله الرحمن الرحيم
السلام عليكم ورحمة الله وبركاتة

The Defence Science and Technology Group (DSTG) are pleased to release FRONTIER's Third Volume featuring the theme "Enhancing Defence Capabilities Through Innovative Approach".

The maintenance, enhancement and upgrading of defence capabilities to function effectively continues to become increasingly challenging and complex if they are not in pace with the rapid development of technologies. Resonating to these challenges, it is integral for the Ministry of Defence (MINDEF) and the Royal Brunei Armed Forces (RBAF) to work closely as a cohesive organisation along with other stakeholders to remain steadfast in developing innovative and creative solutions.

This edition of FRONTIER features two articles, which present a variety of approach conducted by MINDEF and RBAF to improve our defence capabilities, as well as, the integration of digital technologies in everyday operations.

"Physicochemical Properties of Brunei Darussalam Waters – Their Influence on Corrosion Risks" features a study to identify the relation between waters around Brunei Darussalam and their corrosive effects towards our defence assets and capabilities.

"The Importance of Data Governance in an Organisation" discusses about its importance towards effective data management to enhance quality of data, as well as, its security.

Recognising that there are still many other S&T initiatives carried out within MINDEF and RBAF, DSTG wishes to commend our workforce for the continuous contribution made thus far, regardless of its magnitude. With this publication, we hope to instil to our readers a sense of pride and motivation as our organisation strives towards excellence in fulfilling our parts towards protecting our national security.

To conclude, our sincerest gratitude to the journal's Editorial Board, Publication Team, Defence Science and Technology Secretariat (DTS), respectable authors, as well as, the collective workforce that have work hard and contributed towards the successful publication of this journal.

وبالله التوفيق والهداية والسلام عليكم ورحمة الله وبركاته

ABOUT FRONTIER

"A DSTG Initiative"

FRONTIER is a Defence Science and Technology (DS&T) journal formatted under the guidance of the Defence Science and Technology Group (DSTG), for the periodic publication of a curated set of articles, reports and technical papers written by members of the Ministry of Defence (`MINDEF) and the Royal Brunei Armed Forces (RBAF), in support of the ongoing effort to institutionalise knowledge within the organisation. Moreover, through publication and hence sharing of DS&T content, FRONTIER aspires to be a platform that creates awareness, generates discussion and inculcates innovation among members of MINDEF and RBAF.

In alignment with the ongoing digitisation effort spearheaded by DSTG, FRONTIER will be made available primarily as soft copy, via MINDEF Intranet and DSTG Core, both accessible via MINDEF Defence Administrative Network (DAN), as well as, via the MINDEF official website. Limited hard copies of FRONTIER will also be distributed to MINDEF and RBAF's leaderships and made available in MINDEF and RBAF's libraries.

Physicochemical Properties of Brunei Darussalam Waters – their Influence on Corrosion Risks

Dr Nurhazwana Jumat, CSTRAD

About the Author

Dr Nurhazwana Jumat is a research officer from the Centre of Science and Technology Research and Development (CSTRAD). In CSTRAD, she specialises in Tropical Environment Research. She previously graduated with a PhD in Geosciences from Universiti Brunei Darussalam.

Abstract

In this study, physicochemical properties of Brunei Darussalam waters relating to corrosion were investigated. To achieve the objectives of this study, fieldwork was performed for the direct sampling and analyses from 38 test points, which include coastal, riverine and offshore areas. Water parameters such as water temperature, salinity, conductivity and resistivity, total dissolved solids and pH were determined. The findings suggest that variations in physicochemical parameter levels are mainly attributed to distances from water sources, industries and pollution. All coastal and offshore military activities and infrastructure must undergo frequent maintenance to ensure minimal effects of corrosion. Military activities in Brunei River and Tutong River in particular should be underscored in terms of their elevated risk of corrosion. It is recommended that more frequent sampling over an extended period of time is conducted to allow more accurate assessment and long-term monitoring. Additionally, further validation from other definitive measures needs to be performed, such as the determination of the rate of corrosion of the metals making up the military platforms.

Keywords: *Corrosion, Physicochemical Properties, Water Quality, Brunei Waters, Military, Salinity*

1. Introduction

Corrosion is a prevalent problem in the military on a global scale, with vast amount of assets and infrastructures vulnerable to the effects of corrosion. The problems affiliated with corrosion negatively affect equipment and infrastructure and can lead to reduced asset availability, deterioration in performance and increasing weapon system and infrastructure costs. According to a study conducted by the United States Department of Defense, the cost impact of corrosion in the fiscal year 2016 was USD 20.6 billion [1]. Brunei Darussalam is not an exception, and problems associated with corrosion present great obstacles in the operations of the Royal Brunei Armed Forces (RBAF).

In its general term, corrosion refers to the degradation of a material (usually a metal) as a result of its interaction with its environment [2]. Metals are good conductors of electricity and if the environment with which they are in contact is also conductive, then corrosion will occur via an electrochemical process. Exposure to oxidants (such as oxygen or sulfate) destabilises the properties of the metal, and corrosion consequently converts the refined metal into a more chemically-stable form (such as oxide, hydroxide or sulfide). Natural waters, such as the sea and river, act as an electrolyte and promotes the conduction of electricity, and thus accelerates electrochemical corrosion. Corrosion degrades the useful properties of materials and structures including strength, appearance and permeability to liquids and gases.

Brunei Darussalam is situated on the low-lying coastal area of Borneo Island and its population, infrastructures and developments are principally concentrated around the coastal areas. The sea water is naturally very aggressive towards most materials. The Royal Brunei Armed Forces (RBAF) bases have also been built along the coastline, leaving them vulnerable to corrosion. Corrosion is particularly persistent in the Royal Brunei Navy (RBN) and Royal Brunei Air Force (RBAirF). Naval military operations naturally have constant exposure to corrosion as they principally operate and navigate in the sea and river. A steel ship loses structural strength since corrosion reduces the thickness of the hull plates, bulkheads, beams and decks, particularly in aged ships. The aircrafts do not have constant contact with sea water during aerial operations, but they get exposed to sprays of seawater during operations or drills when the aircrafts hover near the sea. The corrosivity of water heavily influences the integrity of not just military vehicles, aircrafts and ships, but also military facilities and infrastructure. Repairing equipment affected by corrosion is not only expensive, but it also requires some downtime and hinders asset availability. Although there are proactive measures to curb the problem of corrosion such as paint coatings, they are not entirely effective and continual maintenance is normally necessary, but not always applied.

In Brunei Darussalam, various researches have been made on this corrosion issue, but existing corrosion studies have been focused mainly on post-corrosion remedies, such as corrosion coatings. Water quality

studies in Brunei Darussalam are conducted regularly by the Water Services Department, the Fisheries Department and the Department of Environment, Park and Recreation, but they are conducted on selected areas of operations and none of these water quality studies are linked with corrosion. Hence, the aim of this study is to evaluate preliminary corrosion risks on military assets based on the physicochemical properties of Brunei Darussalam waters, such as salinity, conductivity and resistivity, total dissolved solids and pH.

2. Methodology

Fieldwork was conducted on 38 selected test points along the country's coastline and in offshore and riverine areas *(Figure 1)*. These test points were strategically selected to warrant as much coverage on Brunei Darussalam's main water bodies and the test points also cover the usual locations for the RBAF military patrols. The test points are classified into three main sections according to the type of water body: Coastline or Inshore test points (Sites 1-16), River test points (Sites 17-33) and Offshore test points (Sites 35-38).

At every test point, the following water properties were measured:
- Water temperature [Unit: °C]
- Water conductivity [Unit: µS/cm]
- Water resistivity [Unit: Ohm.cm]
- Total Dissolved Solids (TDS) content [Unit: ppm]
- Salinity [Unit: PSU]
- pH

An increase in water temperature directly corresponds to a higher corrosion rate because electrochemical reactions necessary for the process of corrosion generally occur faster at higher temperatures [3]. This corrosion process necessitates a conductive medium in the form of ions in the solution or electrolytes, so higher conductivity will increase the rate of corrosion [4]. Salinity is a measure of the amount of dissolved mineral salts present in the water [5], whereas TDS is a measure of the amount inorganic and organic compounds in the water [6]. Both parameters have a positive relationship with the rate of corrosion. Metals corrode faster in an acidic environment where the pH falls closer to 1, as the resulting excess hydrogen ions may become involved in the cathodic reaction which would lead to evolution of hydrogen gas [7].

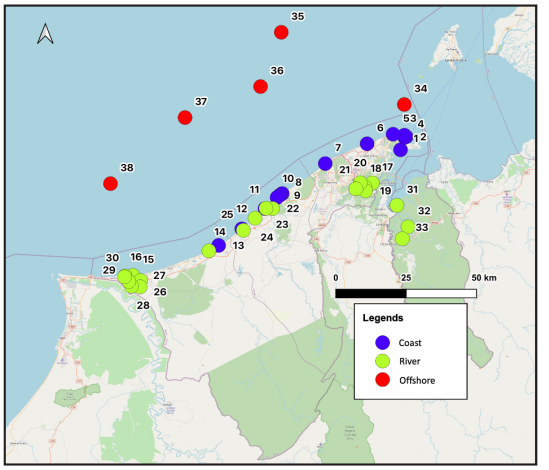

Figure 1: Map of selected test points for investigation of Brunei water properties.

Field measurements presented in this study were carried out for 3 calendar weeks from 15 March 2021 to 02 April 2021. All of the measurements were recorded between 0800 and 13:00 hrs and only on days which recorded fine weather with negligible precipitation. The Hanna Instruments HI 9829 meter was used to take physicochemical measurements of water samples.

Three samples were taken at each test point where the data were recorded on-site, to ensure greater accuracy and minimal error in measurements. For each measurement, the readings were observed and recorded for three minutes at 10-sec interval, for a total of 18 measurements.

3. Results and Discussion

A set of measured and recorded parameters – longitude, latitude, water temperature, salinity, TDS, water conductivity, water resistivity and pH – are presented in *Table 1*. The presented values are the average of three separate readings from three samples taken at each test point, which consists of 18 measurements per test point. The test points are described by their location type and local landmarks *(Table 1, Location)* and their exact locations are given in the World Geodetic System WGS84 *(Table 1; Longitude and Latitude)*. The data obtained have been incorporated into graphs based on their respective parameters, as shown in *Figures 2-6.*

To demonstrate the spatial distributions of the samples based on their respective

Table 1: Investigative results from the selected test points.

Test	Location		GPS Lat.	GPS Long.		Sal. [PSU]	TDS [ppm]	Cond. [µS/cm]	Res. [Ohm.cm]	pH
1	Brunei-Muara Coastline	Serasa Beach	4°59'28.10"N	115° 4'2.56"E	30.3	23413	46830	21.0	23413	8.22
2		RBN Alpha Dockyard	5° 1'57.12"N	115° 5'6.92"E	27.4	21420	42845	23.0	21420	8.20
3		RBN Bravo Dockyard	5° 1'50.33"N	115° 4'51.57"E	25.2	19860	39724	25.3	19860	8.16
4		Muara Beach	5° 2'20.33"N	115° 4'47.21"E	32.9	25162	50329	20.0	25162	8.27
5		Meragang Beach	5° 2'27.59"N	115° 2'33.77"E	31.0	23852	47708	21.3	23852	8.17
6		Berakas Garrison Beach	5° 0'39.22"N	114°57'37.42"E	32.8	25090	50185	20.0	25090	8.21
7		Polo Jerudong Beach	4°56'51.51"N	114°49'35.19"E	33.0	25184	50371	20.0	25184	8.20
8	Tutong Coastline	Penanjong Garrison Beach	4°51'7.16"N	114°41'18.74"E	32.9	25196	50396	20.0	25196	8.24
9		Penanjong Beach (1)	4°50'46.57"N	114°40'49.65"E	32.7	25051	50106	20.0	25051	8.23
10		Penanjong Beach (2)	4°50'23.06"N	114°40'17.27"E	32.6	24985	49975	20.0	24985	8.21
11		Seri Kenangan Beach	4°48'16.10"N	114°37'59.42"E	32.7	25053	50112	20.0	25053	8.26
12		Danau Beach	4°44'22.30"N	114°33'32.89"E	33.0	25262	50529	20.0	25262	8.23

13	Belait Coastline	Sg Liang Beach	4°41’12.71”N	114°29’6.46”E	32.4	24816	49637	20.0	24816	8.23
14		Lumut Beach	4°40’10.67”N	114°27’14.69”E	32.4	24827	49659	20.0	24827	8.23
15		KB Ku Ceria Beach	4°35’31.46”N	114°12’39.04"E	28.4	22109	44223	23.0	22109	8.21
16		KB Port Beach	4°35'24.48"N	114°11'9.37"E	27.5	21522	43048	23.0	21522	8.19
17	Brunei River	Kg Pelambaian	4°53'7.87"N	114°58'37.99"E	18.6	15081	30166	33.0	15081	7.46
18		Kg Pintu Malim	4°52'17.54"N	114°57'13.28"E	16.3	13370	26744	37.4	13370	7.22
19		Kg Bolkiah A	4°51'37.91"N	114°57'20.48"E	12.4	10429	20859	48.4	10429	7.06
20		Kg Ayer Waterfront	4°53'9.21"N	114°56'19.51"E	10.4	8899	17793	56.3	8899	6.96
21		Damuan	4°52'0.61"N	114°55'27.96"E	15.4	12698	25401	39.0	12698	7.01
22	Tutong River	Tutong Waterfront	4°48'14.76"N	114°39'29.33"E	2.39	2265	4530	221	2265	6.48
23		Kuala Tutong	4°48'16.70"N	114°38'12.72"E	7.06	6222	12439	81.0	6222	6.91
24		Kuala Tutong mouth	4°46'23.99"N	114°36'7.85"E	24.3	19242	38488	26.0	19242	8.06
25		Telisai Bridge	4°44'4.98"N	114°33'52.95"E	22.4	17940	35883	28.0	17940	7.52
26	Belait River	Mumong	4°34'29.24"N	114°14'7.75"E	0.60	608	1216	822	608	5.60
27		-	4°33'17.19"N	114°14'3.88"E	1.14	1122	2243	446	1122	5.87
28		V Plaza/ Belait Water-front	4°33'23.62"N	114°12'22.12"E	2.11	2007	4015	249	2007	6.13
29		Rasau By-Pass Bridge	4°34'18.33"N	114°11'52.41"E	2.50	2354	4707	212	2354	6.20
30		KB Port	4°35'10.97"N	114°11'3.77"E	3.11	2903	5807	172	2903	6.35
31	Temburong River	Temburong River mouth	4°48'50.94"N	115° 3'20.55"E	3.86	3542	7083	142	3542	6.88
32		-	4°44'45.07"N	115° 5'27.92"E	0.01	14.3	29	35246	14.3	6.90
33		Pekan Bangar Bridge	4°42'28.03"N	115° 4'24.05"E	0.01	8.84	17	57414	8.84	6.80
34	Offshore	Near American Wreck	5° 8'7.55"N	115° 4'45.84"E	29.5	22848	45700	22.3	22848	8.29
35		-	5°21'55.18"N	114°41'9.55"E	32.7	25047	50098	20.0	25047	8.29
36		Near Fairley Oilfield	5°11'32.88"N	114°37'10.26"E	33.0	25265	50534	20.0	25265	8.29
37		Near Osprey Oilfield	5° 5'37.75"N	114°22'40.40"E	33.1	25304	50614	20.0	25304	8.29
38		Near Ampa Oilfield	4°53'0.14"N	114° 8'22.07"E	31.5	24273	48552	21.0	24273	8.28

parameter values, infographic maps have been presented using the QGIS software *(Figures 7-11)*.

3.1. Analysis based on type of water body

There are distinct variations in parameter values observed by the different types of water body from which the samples were measured from. Saltwater is expected to have greater concentration of dissolved salts in its content, which naturally increases the salinity of the water, as well as, its electric conductivity because the dissolved salts conduct electric current. High levels of TDS, salinity and conductivity generally elevate the risk of corrosion. As seen in *Table 2*, the resulting parameter levels of the samples from the different types of test points conform with the above phenomenon:

- The average values for the conductivity, TDS and salinity of the river samples are remarkably lower in values as compared to samples measured at the coastline and offshore test points.
- Inversely, the average resistivity value for river samples is also larger than those of coastline and offshore.
- Additionally, it was also observed that the average pH values for river samples are lower than the average values from coastline and offshore.

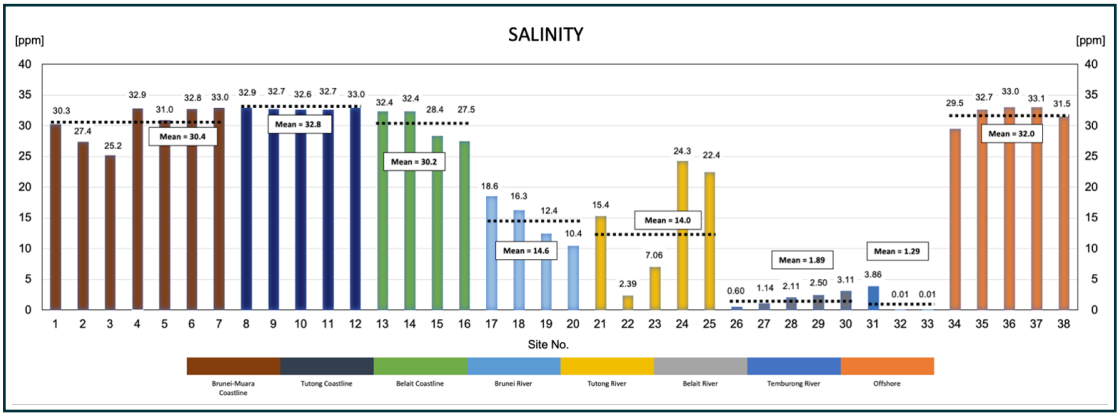

Figure 2: Salinity values for all test points.

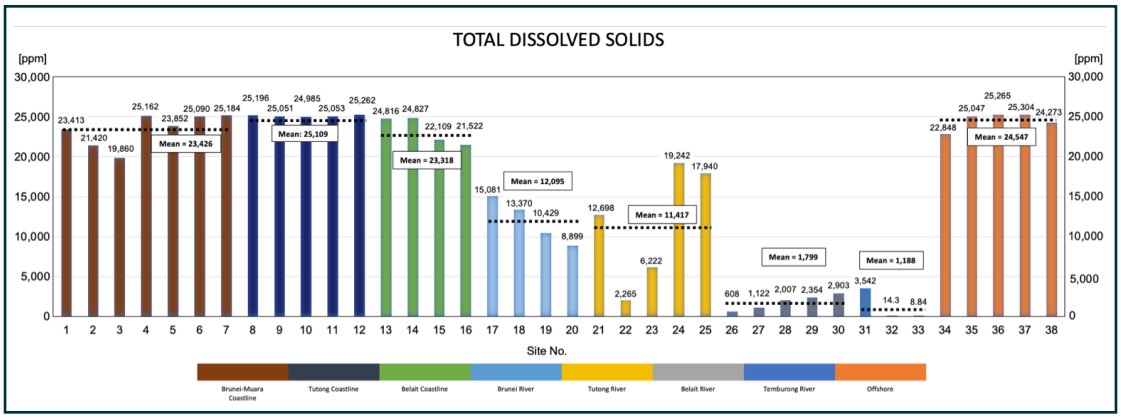

Figure 3: Total Dissolved Solids values for all test points.

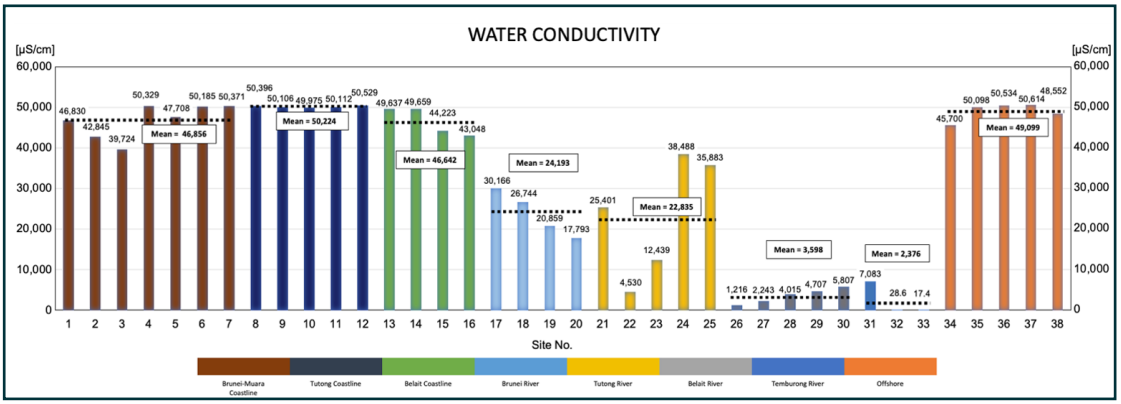

Figure 4: Conductivity values for all test points.

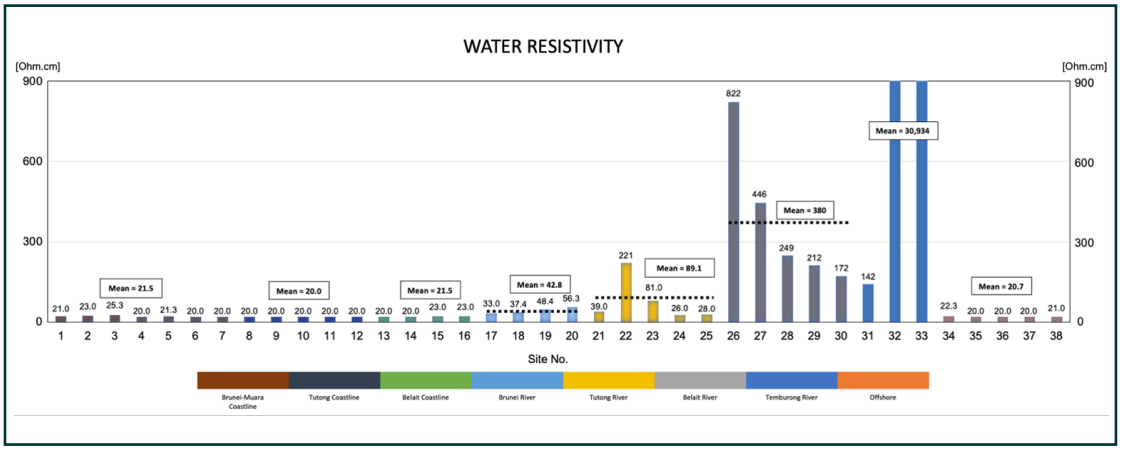

Figure 5: Resistivity values all test points.

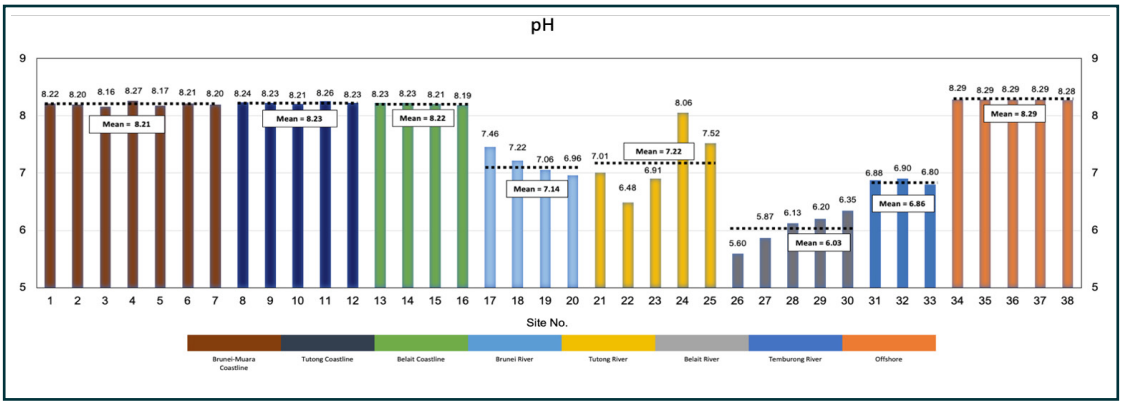

Figure 6: pH values for all test points.

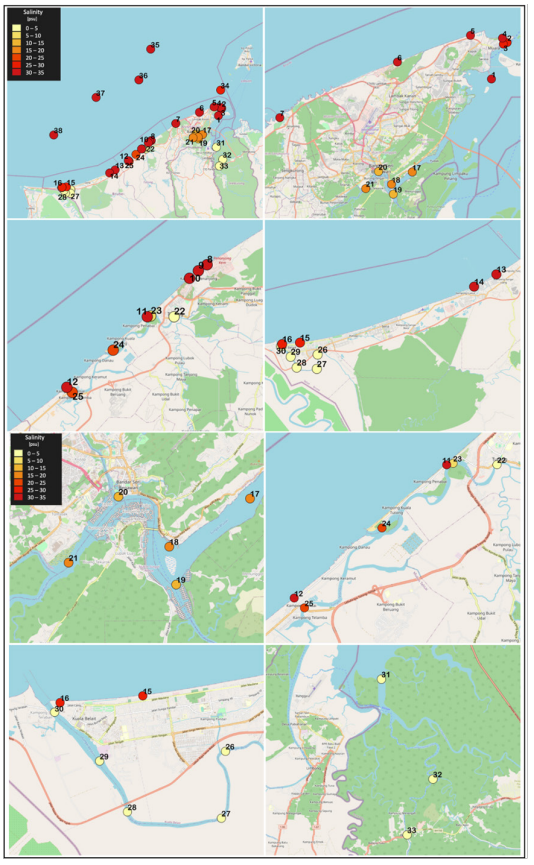

Figure 7: Spatial distributions for salinity.

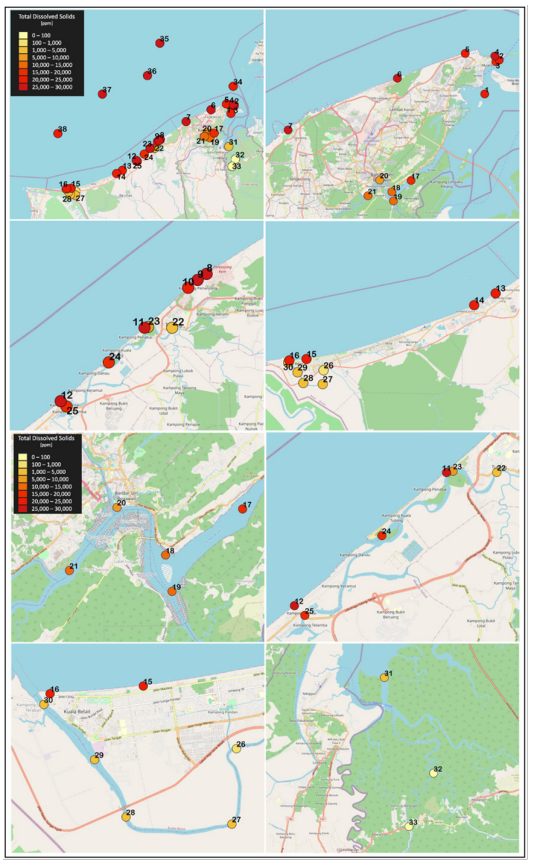

Figure 8: Spatial distributions for TDS.

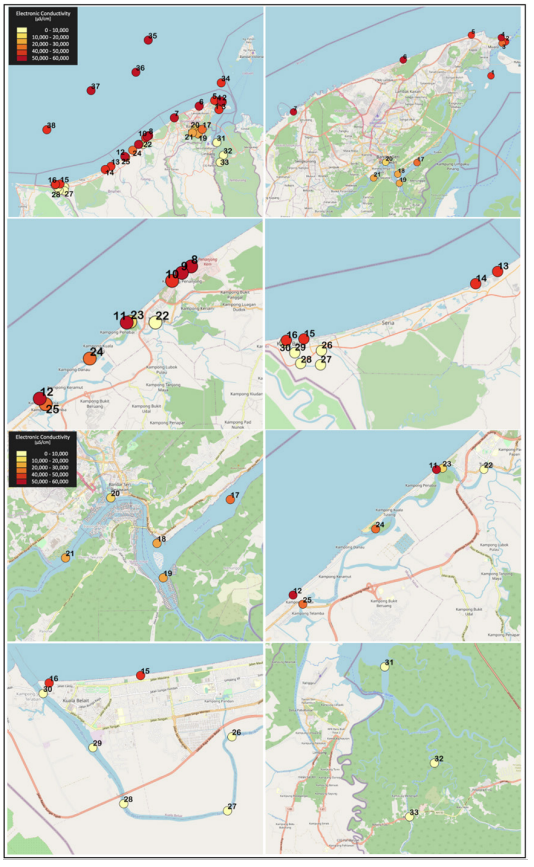

Figure 9: Spatial distributions for conductivity.

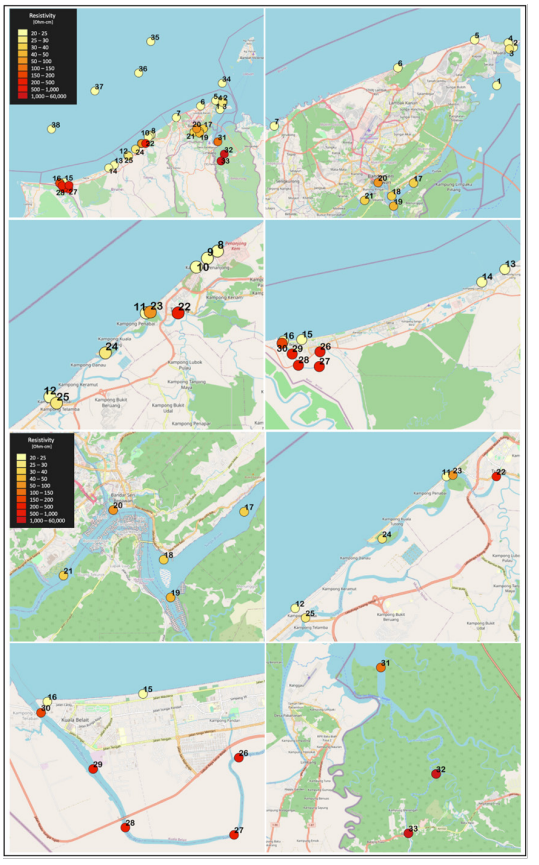

Figure 10: Spatial distributions for resistivity.

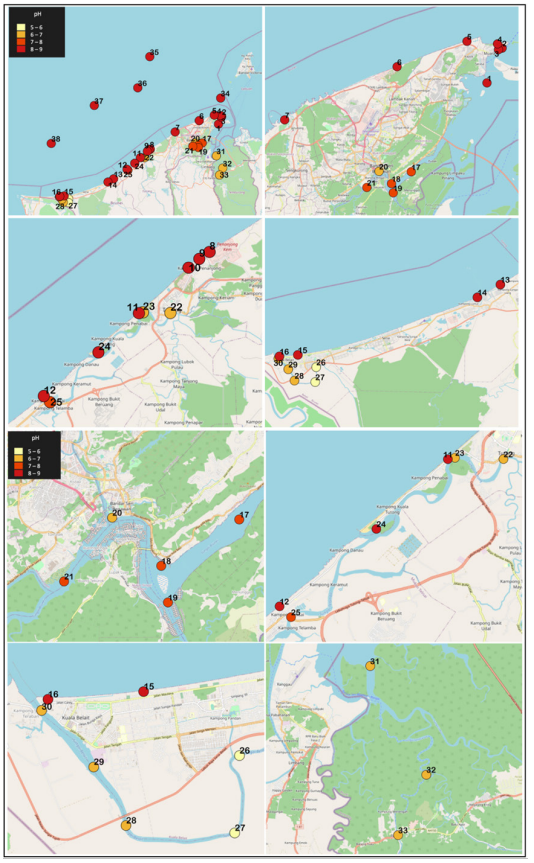

Figure 11: Spatial distributions for pH.

When compared to the expected threshold values for the water parameters which have been shown in *Table 3* for comparison, the overall average values of conductivity, TDS, salinity and pH in this study suggest that the Brunei waters, regardless the type of water body, are mostly highly saline and hence theoretically have a high susceptibility for the occurrence of corrosion.

Table 2: Average values for the different water body types.

Parameter	Coastline	Offshore	River
Water Temperature [°C]	28.9	29.3	29.9
Conductivity [µS/cm]	47,855	49,100	13,966+
Resistivity [Ohm.cm]	21.0	20.7	5,604^
Total Dissolved Solids (TDS) [ppm]	23,925	24,547	6,983+
Salinity [PSU]	31.1	32.0	8.39+
pH	8.2	8.3	6.8+

Notes:
+ Lowest value across the three types of water body.
^ Highest value across the three types of water body.

3.2. Analysis based on individual parameters

It was observed that salinity, TDS and conductivity have a positively-correlated relationship, whereby an increase in salinity results in greater TDS and conductivity levels *(Figure 12)*. Salinity is a measure of the concentration of salts in the water, whereas TDS is a measure of the dissolved combined content of all inorganic and organic substances present not limited to salts. Since the electrical conductivity is a measure of the capacity of water to conduct electrical current, it is directly related to the concentration of salts dissolved in water, and therefore to salinity and TDS. While conductivity measures how well electricity is able to flow through the water, resistivity measures how much the water can resist the flow of electricity. Following this theory, resistivity and electrical conductivity are inversely proportional to each other.

In this study, there are several factors which have been observed to be influencing parameter values:

- Mixing between sea water and fresh water
- Industrial pollution
- Geology and morphology of river
- Urban activity and sewage run-offs

Table 3: Threshold values for the different water body types [8].

		Salinity [PSU]	TDS [ppm]	Conductivity [µS/cm]	pH
Fresh water		< 0.5	< 1,000	150 - 500	6.0 – 8.0
Saline water	Slightly saline		1,000 – 3,000		
	Moderately saline	3.0 – 5.0	3,000 – 10,000		
	Highly saline	5.0 – 28.0	10,000 – 35,000		
Ocean water			35,000	55,000	8.2

Mixing between sea water and fresh water. The mixing of sea water with fresh water at the estuary or the mouth of the river can increase or decrease the levels of salinity, TDS and conductivity. As fresh water contains less than 1,000 ppm of total dissolved solids, the input of fresh river water into the sea water will decrease the aforementioned parameter levels. Inversely, the input of sea water into the river will increase the values. Coastline samples at Site 2 (RBN Alpha Dockyard) and Site 3 (RBN Bravo Dockyard), as well as, Site 15 (KB Ku Ceria Beach) and Site 16 (KB Port Beach) are affected by this mixing, due to their locations closer to the estuary, and show relatively low salinity, TDS and conductivity values *(Figures 2 to 4)*.

Similarly, river samples experienced a distinct pattern for all four rivers in Brunei Darussalam, whereby the salinity, TDS and conductivity levels of the river decrease as the samples move farther inland, away from the estuary, with the exception of Site 21. In terms of pH, the rivers are generally within the normal range (pH 6 – 8), with the exception of Site 24 (pH value of 8.1). This may also be a consequence of the mixing with sea water from the coast, as Site 24 is located at the estuary where the sea meets the river.

Industrial pollution. An oil spill or addition of other organic compounds is known to cause a water body to become less conductive, and naturally more resistive, as these elements do not break down into ions [9]. Hence, oil run-offs from vessels may be the be the reason behind the below average

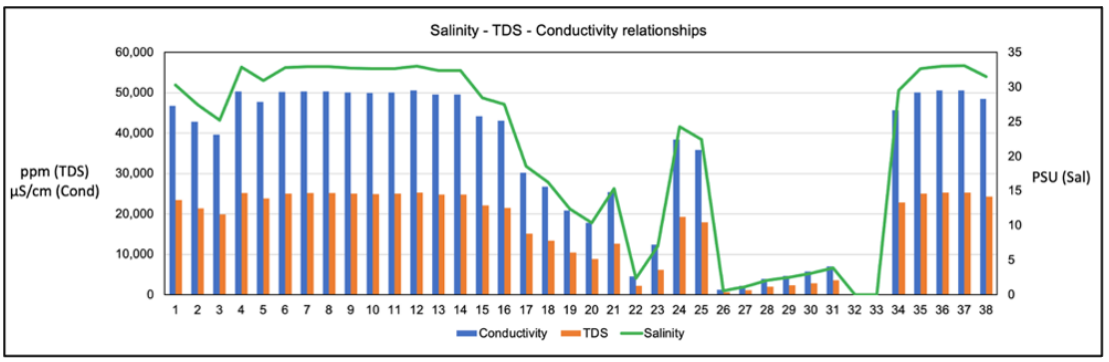

Figure 12: Relationships between salinity, TDS and Conductivity levels.

conductivity values at Site 2, Site 3, Site 15 and Site 16, which are near dockyard areas *(Figure 4)*.

The Stone Quarry Industry concentrated in Madewa is situated in close proximity to Site 21, which may have increased the salinity level of the samples. When it rains, the water will flow through the soil, dissolving and picking up soil run-offs from the quarries into the river [10].

Geology. Lowland tropical peats are characterised by high acidity; the pH of both peat and surface waters is highly acidic ranging from pH 2.3 to 4.5 [11]. The run-offs from the peat swamp forest concentrated along the basin of the Belait River may explain the relatively more acidic characteristic of the Belait River, which has a mean value 6.0, comparatively lower than the overall average pH value of 6.8 for all rivers. This finding is in line with data obtained from the Department of Water Services from the Ministry of Development *(pers. comm., 2020)* which showed lower pH values for Belait River, as shown in Figure 13. As metals corrode faster in an acidic environment, such conditions present in Belait River may result in adverse effects on military assets.

Morphology of river. As the Brunei River and Tutong River have greater width and hence experience bigger exposure at the estuary, this results in a greater volume of mixing with sea water (which naturally has higher salinity, TDS and conductivity) *(Figures 2 to 4)*. Belait River, on the other hand, is narrower in width and longer in length. Temburong River is also relatively very narrow and particularly has many meanders. As such, Brunei River and Tutong River are likely to be relatively more corrosive as compared to the other two rivers, based on the mixing of water promoted by the morphology of the river.

Urban activity and sewage run-offs. Waste water can contain traces of cleaning agents, chemical detergents or other contaminants which are alkaline. Therefore, the disposal of chemicals into the water will increase the pH levels. Hence, Kg Ayer settlements and their residential sewage run-offs into the Brunei River and the Tutong Town run-offs into the Tutong River may have resulted in the higher pH values, when compared to the relatively pristine Belait and Temburong rivers where there is less anthropological input. Higher pH values suggest lesser susceptibility

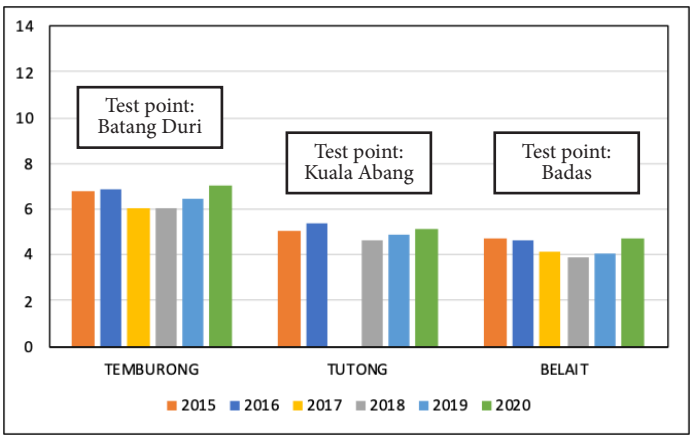

Figure 13: pH data between 2015 and 2020 obtained from the Department of Water Services (pers. Comm., 2020).

to the harmful effects of corrosion to military metals.

3.3. Global patterns of salinity

In terms of global climatology patterns, atmospheric temperature is generally the highest at the equator and the lowest near the poles. Based on this knowledge, higher rates of evaporation at the equatorial regions, including Brunei Darussalam, are expected, which will result in higher salinity. However, various studies have confirmed that the salinity along the equator seems to be a little lower than at slightly higher latitudes. This is because of water input and removal. Equatorial regions get a high volume of rain on a regular basis, which effectively dilutes the surface water along the equator. Hence, higher salinities are found at subtropical, warm latitudes with high evaporation and less precipitation.

The accelerated corrosion experienced on the relevant operational platforms owned by the RBAF may possibly be due to a limited understanding of the local and regional South China Sea water properties by the original equipment manufacturer (OEM). The corrosion-plagued Blackhawk S-70i helicopters, which are severely affected from the avionic nose, the cabin to the tail fin, are manufactured by American-based Sikorsky Aircraft subsidiary, PZL Mielec in Poland. Prior to the Philippines' recent acquisition of the S-70i helicopters, there were no other militaries in the Southeast Asian region which operate a similar platform [12].

Based on gathered salinity data summarised in *Table 4* and supported by the remotely-sensed surface salinity data from NASA from *Figure 14* [13], Brunei Darussalam waters are not necessarily more saline than the OEM countries; in fact, the salinity level for Brunei sea water is comparatively at the lower end of the global surface salinity spectrum due to high volume of rainfall experienced in equatorial regions. Nonetheless, the overall average values of conductivity, TDS, salinity and pH obtained in this study still suggest that the Brunei waters, including river water, are still more saline than the expected threshold values *(Table 3)* and theoretically have a high susceptibility to corrosion.

Local water salinities may be influenced by local activities. Dredging works by the nearby Hengyi Industries in Pulau Muara Besar adjacent to the RBN Muara Base may have accelerated the salinisation process by increasing the volume of area the seawater can enter through [21]. This pushes salty water deeper into tributaries and further up the mainstream of the river. However, an extensive understanding or baseline data of the salinity levels and other physicochemical properties in relation to corrosion at the Muara Base and the adjacent Pulau Muara Besar is necessary to perform any conclusions. This can be achieved by traditional data collection or via the placement of sensors at respective test points of interest to monitor real-time Brunei Bay data, which will provide significant contribution to the military.

Nonetheless, the continuous global sea level rise as a by-product of climate change is a huge cause of concern for Brunei Darussalam, as an island nation with our national infrastructures and resources located along the coast,

Table 4: Salinity levels for sea waters near OEM countries of corrosion-plagued operational platforms.

Platform	OEM / Builder	Location of Manufacture	Salinity Level [PSU]
KDB Darussalam Class patrol vessels	Lürssen Werft	Bremen-Vegesack, Germany	34 – 35 [14], [15]
KDB Ijhtihad Class patrol vessels		German Bight, North Sea	
KDB Mustaed Class fast attack crafts	Mariteknik Shipyard	Tuas, Singapore	28 – 32 [16], [17], [18]
KDB Waspada Class fast attack crafts		Singapore Strait	
KDB Serasa Class amphibious warfare crafts (landing crafts)	Transfield Shipbuilding	Henderson, Australia	35 [19]
		Indian Ocean	
KDB Damuan Class landing crafts	Cheverton Workboats	Cowes, Isles of Wight, England	34 – 35 [19]
		North Sea	
Blackhawk S-70i helicopters	PZL Mielec (Subsidiary of Sikorsky Aircraft)	Wojska Polskiego, Poland	2 – 13 [20], 4 – 7 [4]
		Baltic Sea	

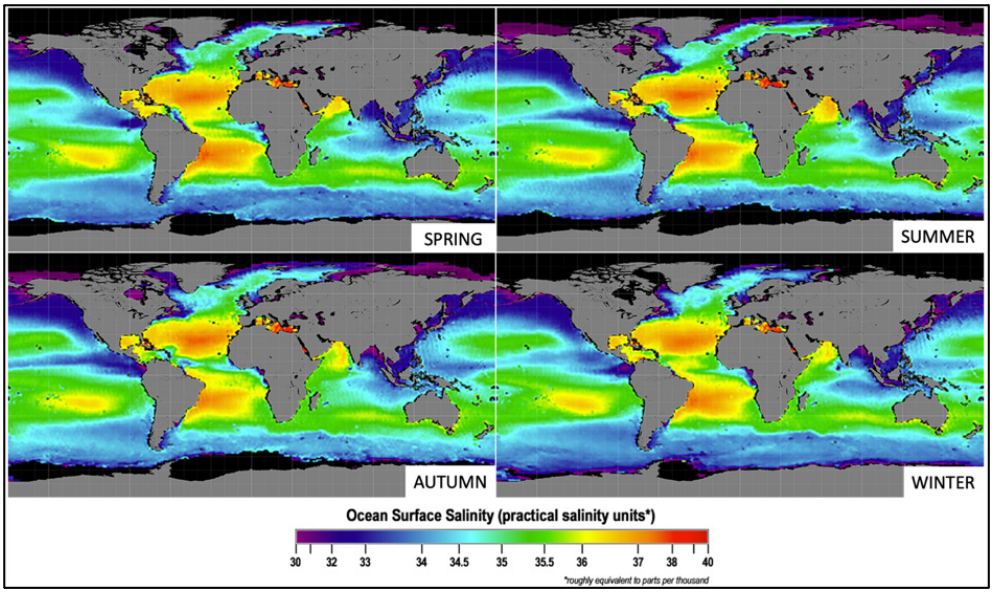

Figure 14: NASA Aquarius maps showing sea surface salinity from 2011 to 2015 [16].

including RBAF military bases – notably the Muara Naval Base, the Berakas Garrison and the Penanjong Garrison. The National Oceanic and Atmospheric Administration highlighted the alarming acceleration of sea level rise, from 1.4 mm per year throughout most of the 20th century to 3.6 mm per year from 2006 to 2015 [22]. As the sea levels rise, the "salt front" (location of the freshwater-saltwater line) may progress further upstream [23]. This increasing risk of salt water intrusion, in turn, will lead to elevated corrosion threats.

4. Conclusion

Corrosion aggressiveness is a function of various factors. Some of these factors include the physicochemical factors of the water body, which have been studied in this paper, such as its salinity, TDS, electrical conductivity and resistivity and pH. In Brunei Darussalam, these factors are associated with the distance from water sources (and consequent mixing between fresh and saline water bodies), the distance from industrial infrastructure and pollution, as well as, geology and river morphology. From this study, it was found that all coastline and deeper offshore waters have high salinity, TDS and conductivity levels. For riverine areas, Brunei River and Tutong River have relatively higher salinity, TDS and conductivity levels compared to Belait River and Temburong River. Additionally, it was also observed that the Belait River is slightly acidic with lower pH levels, making it more vulnerable to the effects of corrosion.

The RBAF should exercise caution when planning operations in these areas, and maintenance requirements should be taken into consideration when considering the frequency of these activities so as to not aggravate the risk of accelerated corrosion on their operational platforms. The corrosion-related physicochemical parameters must be constantly studied and monitored to ensure minimal risk of corrosion. It should be noted that the study was conducted based on a one-time sampling, hence the data is useful but is not entirely conclusive. A more frequent sampling, conducted at least twice in a day over an extended period of time would prove to be beneficial. It is suggested that placing sensors at respective test points of interest for monitoring real-time Brunei waters data will be of great assistance and will provide improved recommendations to the RBAF.

Nonetheless, the physicochemical characteristics constitute only a fragment of what influences corrosion aggressiveness of water. Although they have helped in providing preliminary guidance in terms of identifying the corrosivity of the Brunei Darussalam waters, further validation from other definitive measures needs to be performed, such as the rate of corrosion on selected military metals from operational platforms, for better predictions in terms of the corrosion experienced by the RBAF.

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The Importance of Data Governance in an Organisation

Lt. Col. Caslindawati Samil, DITU & Suciyati Haji Sulaiman, UBD

About the Authors

Lt Col Caslindawati Samil is the Chief Information Officer for the Defence Information Technology Unit (DITU), Ministry of Defence. She is responsible for the implementation of the Brunei MINDEF IT strategy and policy. Her IT journey of twenty years has seen her in the creation of MINDEF website with the Public Relation Office, as well as the transition of MINDEF C2 system with Directorate of Operations and she has been involved with the Brunei MINDEF's e-Government Projects. She was a research officer at the Directorate of Intelligence whilst witnessing the transition of security section onto the MINDEF Defence Security Branch (DSB) in 2012. Her responsibility to the MINDEF Permanent Secretary is for the implementation of the MINDEF digital strategy framework and the secretariat for the MINDEF IT Security Committee (MITSEC).

Suciyati Haji Sulaiman is the Deputy Director at the Language Centre, Universiti Brunei Darussalam, and has more than ten years teaching experience in English language and Professional Communication skills, teaching UBD students, as well as professionals from private and government agencies. She has also taught and supervised students from Defense and Security Studies programme at the Defence Academy Royal Brunei Armed Forces. Her involvement and expertise in Professional Communication Skills have taught numerous batches of international officers from Southeast Asian regions from various ministries, including Brunei Ministry of Defence. Apart from teaching, her role is also designing and coordinating language programmes for UBD community, government and private agencies in Brunei, including international institutions. She is also involved in consultation of various editorial services, including interpreter for various agencies, such as the Language and Literacy Bureau and the Banking industry in Brunei, and has published in few international journals in language education.

Abstract

The purpose of data governance is to promote effective data management, in terms of enhancing the quality of data and strengthening the protection of these data. As the country is embracing the industrial revolution 4.0, where decisions and actions made are data driven, data now becomes valuable. Thus, with growing data available within an organisation, effectiveness in managing a data should be one's priority by not relying on the IT department but rather the subject matter experts of their own data. Governance is identified as interactions between actors and organisations, of which aims to realize a collective goal, through influencing groups, in order to manage data efficiency. This paper emphasizes the importance of implementing a framework of data governance within the government organisations in order to maintain quality of data, strengthen the protection mechanism of data, as well as to ensure there are no redundancy that may lead to waste of resources. In this paper, data management strategies are highlighted, whereby in order for data governance to be implemented, various literature has stipulated and identified the three important elements, namely people, processes and technology, of which are vital keys. Furthermore, the paper will further elaborate the required structure and recommendations on the implementation of a framework for Brunei to adapt with guidelines from the ASEAN framework, where it suggests that goals should be identified, and to understand the benefits in order to plan and implement. In addition, it requires close monitor and control to ensure the quality, accessibility and integrity of data.

Keywords: *Data security, Data governance, Cyber security, Data protection, IT security, Information technology, Data Management, Data auditability, Data lifecycle*

1. Introduction

Data governance has now been taken on a higher level of importance in enterprises and governmental institutions [1], and now Brunei Darussalam has embarked on the digital era of digitalising of data. It has been acknowledged that data is a valuable resource and has grown increasingly prevalent among government agencies and IT executives [1]. With the growing data, it is important to manage data effectively, and thus, creates pressure to have strong handle on what data is to be stored, where, and how the data should be used.

Data governance is defined as the processes, policies, standards, organisation and technologies that are required to manage and ensure the availability, accessibility, quality, consistency, auditability and security of data in an organisation [2]. There were numerous definitions of data governance by accordance to the purpose and objective of specific organisations. In the context of Brunei Darussalam and within the capabilities of an organisation, data governance should be defined as managing data as a strategic enterprise asset. With this definition, it allows data governance to specify decision rights and accountabilities for an organisation's decision making about its data. Furthermore, recognising data as an asset implies the importance of data governance in order to manage data effectively.

With the emergence of new technologies that involve sophisticated analytic-based techniques and computing power that enables data-driven decision [3], data becomes valuable. As a result, IT plays a critical role, where experts safeguard the IT assets of an organisation, as well as the data ownership. This safeguard ensures appropriate controls in order to protect these assets from cyber-attacks, theft, misappropriation, and non-compliance with privacy laws and other regulations [3]. Therefore, it is important to note that IT and data governance is able to provide the structure and rules to ensure data accuracy and availability while managing associated risks [4]. In order for it to be achieved, there is a need for a more detailed information, policies, procedures, guidelines, work processes, to run IT operations effectively within an organisation [4].

Data governance provides a clear ownership and accountability of the data within an organisation, where it parallels the capabilities of corporate governance, as well as, IT governance at the data level, thus making data governance a subset of IT governance [4]. Furthermore, in order to achieve the full potential of information assets, it requires the collaboration efforts of people, processes and technology towards the same goals set by an organisation, and this can be made possible by acquiring an effective IT and data governance program [3]. This paper emphasises on the required data governance structure and a possible framework to be adapted in Brunei based on other literatures and the ASEAN framework as a guideline for Brunei to execute accordingly in the perspective of cyber security.

2. Data Management Strategy

Data governance in an organisation

is an added value to its operational capability. This can be exemplified where the Pentagon is currently publishing policies and procedures of best practices in their organisation's data management operations to ensure the US armed forces have the "data advantage" over its adversaries in future conflicts [5], which may be achieved through advanced machine learning (ML) and artificial intelligence (AI) that they planned to develop. AI as the simulation of human intelligence in machines and ML as the application of AI provides the ability to automatically learn and improve experience through means of analysing data, monitoring behaviours' pattern and decision-making. A clear data management is crucial in generating bigger data in the future. There is a need to know the most sensitive and critical data within an organisation so more resources can be allocated in order to protect the data effectively [6]. Some parts of the resources are the roles of IT organisations or departments within the government ministries itself.

Brunei Darussalam is yet to witness the scheduled government data centre building that is planned to be initiated by this year, called the National Centralised Data Base (NCDB). The Brunei Government houses important information accessible by the public at data.government.bn and this data sharing platform shows transparency within the government services and the responsibility of managing such data lies within the respective government agencies [7]. The NCDB as the national information hub holds common data such as names, addresses and phone numbers that will be generated by the application programming interface (API). which allows two software applications to talk to each other [8]. API also provides another layer of security by communicating only the necessary small packets of data for transactions. This information hub is an initiative towards the ASEAN Digital Data Governance framework for a clear data management and transparent cross-border data flow.

Data governance is the capability within an organisation to assist in protecting high-quality data throughout its data lifecycle which includes data integrity, security, availability and consistency. Data governance includes people, processes and technology that enable appropriate handling of the data across the organisation [6]. People or the "Organisation" define roles and responsibilities of staff, to educate and adapt to technology and process [9]. Process are the policies for processes from data creation to disposal. Technology is the "Standardisation" on the organisation's data model with related technologies and tools where the data integration infrastructure is a technical component that automates processes. Data governance supports an organisation's data management strategy [10], and such data management framework provides the organisation with a holistic approach to collecting, managing, securing, and storing data by considering the data management areas of data accessibility, data availability, data quality, data consistency, data security and data auditability. The data management can be envisioned as a wheel with data governance as the hub.

The minimum security requirements are informed by the type of data that

needs to be protected and this can be done by performing a risk assessment and looking at the CIA triad namely Confidentiality, Integrity and Availability [11]. There are similarities in data criteria of how the data governance should operate [12]. *Figure 1* summarises the linkages of data lifecycle and the right combination of people skills, internal processes, and the appropriate technology [13]. The data governance framework encompasses everything from the people and process behind data governance to the technologies used to manage data [14].

Figure 1: Steps in establishing a data governance framework and component of data governance.

3. Scope of Data Governance

Data governance is the basis of security that ensures that the right people have the right access and data security makes sure that enterprise data is protected. Data governance program policies should include the ownership outlining the accountability for those responsible for data and data assets by collaborating Business and IT [6], the accountability and decision rights clearly define and should bring the right team on board the data governance strategy, and hold the CDO, data stewards, data owners, and employees accountable [14]. Ownership will assign responsibility to appropriate levels in the organisation for managing and protecting the data [6].

Determine accessibility through data strategy and policy development by determining who can take what actions, with what data, under what conditions, using what methods [6]. The strategy should include of what data should remain on-premises, reside as private information in the cloud or made public in the cloud (data as a service).

Setup Stewardship model, a trusted model ensuring the credibility of the data sources and in control of the data lifecycle in which expectations and results can be managed by having the data governance open and visible, with clear established decision-making processes [14]. The model also assist in creation of data catalogue and classifying risk.

Identify Risk and Security are the two major drivers for organisation to engage in data governance in addition to any business outcomes. Identifying safeguards to protect data, providing integrity controls to provide the quality and accuracy of data [6]. Thus risks can be eliminated by having the stewardship model to ensure data ownership.

Develop change management through education and training for data owners and employees on the basic principles of data governance and establish an ongoing training program in maintaining the focus on data governance. Data governance is also a collaborative effort that creates a culture to build the organisation and keep data safe [14], by creating feedback loops and changing control processes for governing data.

The Brunei Government has its own information security classification especially for documents and at the ASEAN level, it also mentions data classification frameworks for the use of private sector businesses. This classification can be applied to the organisation's datasets for cyber security controls. The following security controls might apply for sensitive datasets [13]:

• Enterprise-wide governance controls and processes – a data steward must be assigned to each dataset and authorises access before access to a dataset is granted.
• Security and access controls – users must be vetted before gaining access to the data and multi-factor authentication must be used to gain access to the data.
• Storage and infrastructure controls - Storage solution must have data encryption capabilities and data must be stored on an infrastructure that is on local hosting in the country.

The data governance parallels itself with the corporate governance as IT governance which makes data governance a sub element of IT governance at data level. Rapid growth of an organisation and simultaneous occurrence of a project to develop an information system to support it can cause a duplication of data and inconsistency among data. Overlapping data will slowly lose its consistency and when migration process is conducted due to necessity for data integration, the problem that concerns decision-making about which data is viable among inconsistent data is constantly raised, as decision-making and business intelligence rely on quality of data [9].

4. The Data Governance Structure

The Brunei e-Census data are to be used for others as well, especially those that are related to the economy. A steering committee was established to cater to the Brunei national data coordination and to comply with any specific data governance framework [15]. The responsibility of an organisation is to ensure that the data is correct, available, reliable, and fits a purpose. IT is responsible for the infrastructure that holds, process and reports on the data [2]. The data governance program drives the organisation businesses in their decision- making through the use of the data. There is a need for IT and organisation businesses to work together to align data and IT initiatives. Accountability for data should not rest at the organisation's IT department, instead the subject matter experts of the organisation are in a better position to be accountable for the CIA of the data [11]. The following governance roles and responsibilities are recommended:

The Data Governance (DG) council [2] is the data owner who has the enterprise level authority and accountability under legislation for the collection and management of the organisations' data. It consists of executives from various departments who have interest in the data asset management. They are responsible for endorsing policies, resolving inter-department issues, engaging the IT Council at the strategic level, strategically aligning business and IT initiatives, and reviewing budget submission for IT and non-IT related projects. Conflict resolution is the

most important role of the DG council especially when the same data has different usages to an organisation.

Data Domain Custodian (DC) is responsible for defining and implementing safeguards to ensure protection of data and this is done in accordance to the policies and procedures approved by the data owner. They are also responsible for the quality of asset data and resolving issues raised in user group meetings [2]. DC is responsible for endorsing data management plan, end ring data cleansing plan, ensuring data is fit for purpose, converting strategic plans into tactical plans, change management, and stakeholder management. This is the collaborative level that is represented by all business units [16].

Data steward is responsible for the quality, integrity and use of datasets on a day-to-day basis by managing multiple datasets and applying relevant policies which include the information security classifications while safeguarding the data from unauthorised access. Data steward has the detail knowledge of the business process and data requirements as well as possess good IT knowledge to be able to translate business requirements into technical requirements [2]. They are responsible for carrying out tactical plans, manage user group meetings, train and educate data users [16].

The information technology service providers (ITSP) provide input to security controls but the data custodian and/or data steward has the final decision [11]. *Figure 2* is the Data Governance Framework and quality of data which is a viable base to enlarge the scope of Big Data services [9]. Big Data services require the quality of data, however it must be open to corporate governance for successful services implementation in order to achieve the objective of the organisation. ITSP will provide support to implement governance controls and processes. This group includes the technical teams that provide system support and manage access to the data including information systems [2].

User groups are the data stakeholders from various departments that consist of people who collect data, process and report off the data. The

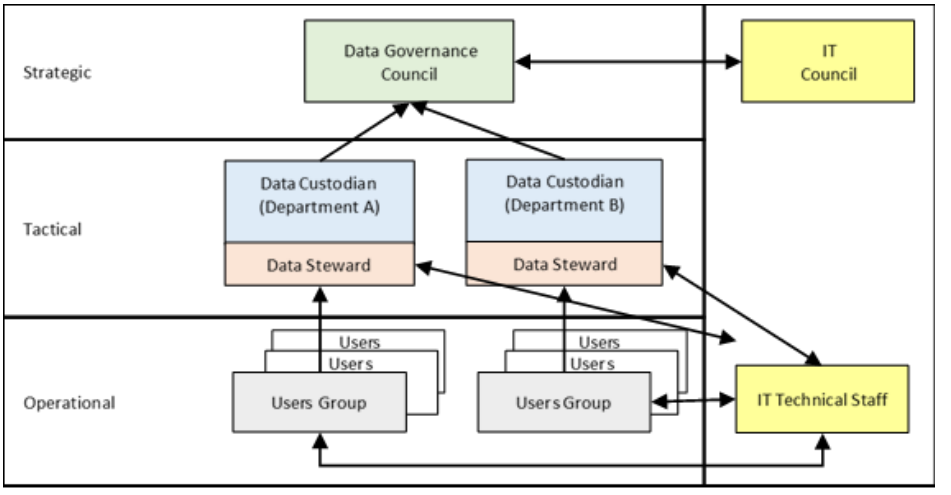

Figure 2: The Data Governance Structure.

technical IT staff are also invited to the user groups meetings so that their technical expertise is available during the meeting. This is also a venue where urgent operational data issues can be tabled. The business engagement with IT should be at a strategic, tactical and operational levels to ensure that IT and businesses are kept informed and IT initiatives are aligned with the business data governance objectives [2].

5. The Data Governance Framework

In terms of protection data against threats, organisations need to be able to select which data to protect and how to maintain its protection. Managing data in a structured, responsible and law-abiding way will ensure efficiency in order for the security professionals to protect it [6]. The need in prioritisation of the most sensitive and critical data assets are crucial in order to allocate more resources to be able to protect particular data and risk-based approach.

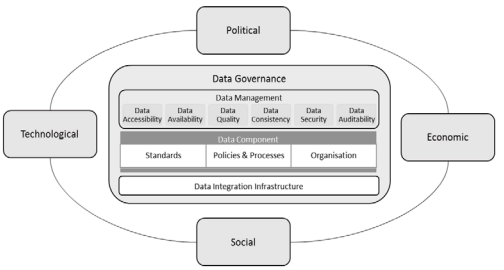

Figure 3: The Data Governance Framework.

Figure 3 illustrates the importance of setting the strategy first then the data processing must be controlled by independent audit authority of IT departments from collection of data to visualisation results. The goals can vary depending on the nature and mission of organisations and should be more clearly defined in the planning phase. The diagram shows the combination for Big Data Governance [9,17] and external factors [18] which is applicable for any Data Governance Framework.

The framework should encompass the following:

Data governance strategies – the objectives, principles and groups for a new (or newly aligned) data governance program.

Data management structures – the underlying concepts and technologies that can help establish and enforce data governance at the application or data level.

Methods – the people, processes and technologies that will be affected by data governance strategies.

Funding and management support are also essential elements of a data governance framework. User engagement will ensure those who consume the data understand and will cooperate with data governance rules.

The data governance framework can be created independently and there are several standards which can help formulate a data governance framework, including COBIT, ISO/IEC 38500, and ISO/TC 215 [13]. ASEAN Data Governance Framework has encouraged members to adhere to the framework for prosperity of economic within the region [19]. Data governance framework considers the goals, data protection enablers, the governance domain, and the principles [17].

The framework addresses the internal governance factors playing a role within the stakeholder network, as well as the external factors influencing the stakeholder network. The external factors for the analysis of data governance were based on the PEST approach used as an analytical tool to identify external key factors causing change in the strategic business environments [18]. PEST stands for Political, Economic, Social, and Technological factors used for identifying and classifying issues that could influence the data governance externally. The description of the PEST factors in relation to data governance based on literature are as follows:

Political are the partnering departments that have to operate in a policy context, and may be influenced by information policies at national or regional levels for information flow across countries, privacy or restrictions in use of some information. It could also be a legal legislation impact to the development and implementation of data driven initiative of the organisation.

Economic refers to demand, supply and competition outside the data driven initiative, which will impact the development and governance of the initiative. This may be influenced by technological development but may as well be linked with levels of globalisation.

Social is linked with the discussion about digital divide referring to a new scale of societal inequality that is based on either having or not online accessibility. New groups in the society that has no access shall lose opportunities on influence, networks, and associated benefits, and as a consequence they become alienated.

Technical refers to external technological developments that have influences within the data driven initiative and can result in new business models. The technologies are developing fast, and developments are addressed in the selected literature. This includes the technologies for attacks of datasets, where they are advancing and are challenging the data security. The decision making within an organisation for investments in new technologies will be impacted and provided by the new possibilities in technological development.

It can be advised from the insights of CIO that a small pilot project should be to begin with, and on a set of data that is found to be problematic and in need of governance. This is to show the stakeholders and managements on the involvement, and to demonstrate the return on investments of data governance activity as agreed upon [10], and it is recommended that it should not have a sudden “big bang initiative” effect. It is also recommended that it should start with manageable or application-specific prototype project, followed by an expansion across the organisation based on lessons learned. The steps should start with defining goals and understand benefits, followed by analysing current state and delta analysis. The next steps would include to derive on a roadmap, convince stakeholders and budget project, where a plan should be developed for the data governance program, and then implement the data governance program, and finally, to monitor and control. The United

States DoD [5] has a similar strategy in data management with ASEAN for the rights on cross border data flows, common data standard through a common classification, similar data catalogue process and storage as well as adapting the industry best practices for data cycle.

6. Conclusion

In Brunei, data governance does exist. However, it is considered as unofficial or project-based due to the lack of structure in placing ownership, roles and responsibilities within an organisation. Nonetheless, for a data governance to be effective and efficient in acquiring data quality, as well as, maintaining its utmost protection of the data, a whole of nation approach should be implemented, especially in compliance with the ASEAN Digital Data Framework. While it is seen to be economics prosperity-driven, the IT capability in data management and data security protection should be embedded when initiatives are implemented. This can ensure that resources of attaining and developing tools to access and monitor data are not repetitive that can cause redundancy within organisations, ministries, and the country as a whole. In addition, it may be a threat or another source of vulnerability to the organisation if it is not properly managed by adopting data governance, where it emphasises security within the framework. Therefore, adopting best practices in developing and implementing a framework of data governance would greatly benefit the country as stipulated and recommended in this paper.

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