

GUIDELINES OF LAKE MANAGEMENT

Guidelines to manage water environment factors that influence proliferation of Salvinia molesta* Mitchell*) on Lake Kwania

National Fisheries Resources Research Institute
Fish Habitat Management and Research programme

Determination of environmental and socio-economic factors that influence optimal fish production levels (ATAAS 7B)

January 2018

Prepared by

Angela Nankabirwa

Contributing scientists

William Okello

Janet Naluwairo

Godfrey Magezi

Henry Ocaya

Acknowledgement

The authors are grateful to the NaFIRRI water quality team, members of the fish habitat research program for their valuable comments and suggestions. All the technical advice by the National Agricultural Research Organisation and financial assistance provided by the World Bank are gratefully acknowledged.

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Executive summary

Over the past 70 years, *Salvinia molesta* D. S. Mitchell has spread from its native range in Brazil to many tropical and subtropical regions. In Uganda, the plant is established in waterways along the Nile including; Lakes Kyoga, Albert and Kimira covering about 13 districts. In addition, it is expected to continue to expand in areas generally where *Eichhornia crassipes* Solms persists. Dense mats of *S. molesta* can suppress growth of native vegetation and degrade water quality, fish and wildlife habitat, and numerous other ecological values. These guidelines present some information on the environment factors that contribute to proliferation of *S. molesta*, and provide recommendations on how these factors can be controlled in order to prevent further spread of the weed in Uganda water bodies.

Overview

Salvinia molesta is essentially a weed of tropical, sub-tropical and warmer temperate zones. The weed is native to South America, particularly south-eastern Brazil. It is considered invasive and is currently found worldwide in subtropical, tropical regions including; Africa, the Indian Sub-continent, south-eastern Asia, warmer parts of Australia and New Zealand, and temperate regions such as southern USA and several Pacific islands. It is dispersed through floods, flowing water, dumping of pond waste, vehicles, boats, fishing gear and animals such as long-distance birds. It is probably through these courses that the weed was introduced to Uganda's water bodies. In fact, its blooming growth is now evident on some of the great Lakes in Uganda including; Lake Albert and Kyoga.

The plant reproduces vegetatively to an extent that even a small piece of stem would be enough to trigger its growth. Waters that are heavily fertilized as a result of soil erosion, waste-water effluents from homes and industries and fish feed application promote its growth. Under ideal conditions, giant *Salvinia* can completely cover water surfaces and form floating mats up to 1 m thick (Thomas and Room 1986). Dense mats of giant *Salvinia* impede transportation, irrigation, hydroelectric production, flood and mosquito control, and destroy habitats, degrade water quality, and can hinder endeavours such as rice cultivation and fishing (Mitchell 1979; Holm et al. 1977). Despite its potentially overwhelming impacts, several environmental factors including; temperature, nutrient availability, salinity, and pH for example within the United States were suggested to limit the distribution and survival of giant *Salvinia*. Studies have shown that giant *Salvinia* survival and growth are affected independently by water temperature, salinity, nutrients, and pH (Cary and Weerts 1984; McFarland et al. 2004; Owens et al. 2004, 2005).

The weed has been reported to die completely when water temperatures fall to freezing for periods of several hours to days depending on ice formation (Owens et al. 2004). However, Uganda experiences an endless summer with typical temperature with 25 - 30 °C, a common range through all through the country and encompassing the best suitable temperature for

optimal fish production. Thus, engineering temperature to winter-like conditions may not be practical for fisheries management in Uganda.

Growth of giant *Salvinia* is reportedly pH dependent, with optimum pH conditions required for maximum growth ranging from 5-7.5 (Owens et al. 2005). Under higher pH conditions, giant *Salvinia* may not be capable of growth that results in problematic coverage (Cary and Weerts 1984; Holm et al. 1977; Gaudet 1973; Mitchell 1979). In shallow lakes such as Lake Kwania that experience regular mixing conditions, productivity remains high leading to pH levels as high as 9. Even with pH as high as that, *Salvinia* is still problematic, moreover forming even blanket-like mats which hinder navigation and fishing on the lake (Figure 1).



Plate 1: Mats of *Salvinia molesta,* other weeds and plants on Kyoga minor lake i.e. Lake Kwania.

Elevated salinities also tend to limit *Salvinia* biomass. For a period of 21 days in a controlled study, giant *Salvinia* survived under low salinity levels but produced significantly less biomass when exposed to salinities of up to 2.5 ppt (Oliver 1993). However, Ugandan lakes have salinities much lower, and as a result this may favour further proliferation of the weed.

Among variables that influence aquatic productivity in aquatic ecosystems, nitrogen and phosphorus are identified as the most limiting. Nutrients contained in industrial, agricultural and domestic waters have caused eutrophication of many lakes, completely changing the ecosystems by explosive growth of planktonic and other plants, further deteriorating the water. Cary and Weerts (1984) and Gaudet (1973) found that *Salvinia* can store concentrations of nutrients (nitrogen and phosphorus) in tissue to sustain growth under stressful conditions. They also found that *Salvinia* grows best when the available nitrogen is in the ammonium form (Cary and Weerts 1984). Amongst pH, salinity and other factors that may prevent *Salvinia* from being problematic, only nutrients are amenable to human control. Anthropogenic influence on lake systems is now a world-wide issue. Efforts have to be made to restore the friendly co-existence of lakes and

human kind through appropriate management of lake: watershed systems to ensure the sustainable use of the resources.

Uganda's involvement in management of water resources

Although Uganda is usually considered to be well endowed with water resources, these water resources exhibit both seasonal and spatial variability. The country encompasses both humid and semi-arid areas and there are not only significant differences between wet and dry years, but also considerable variations in the onset of seasons. In Uganda, fresh water is considered a key strategic resource which is vital for sustaining life, promoting development and maintaining the environment. However, like elsewhere in the world rapid population growth, increased agricultural production, urbanisation and industrialisation are leading to depletion and degradation of available water resources. Moreover, water of adequate quantity and good quality is a key resource in the socio-economics of Uganda as a country and is an important factor in the development process. Some on-going aspects of water resource management include; rapid expansion of the water supply sector with respect to rural and urban water supply and water for production; small-scale irrigation is being promoted and will be of increased importance in the Plan for Modernization of Agriculture while water supply for livestock in pastoral areas is one of the Government priority areas. Sewerage and sanitation requirements increase in step with improvements in water supply and have significant public health implications. Fishing in lakes and rivers is a major component of the country's economy and fish ponds built alongside water courses are increasing in number and importance (Tindimugaya, 2003). However, the international relation continues to influence policy development in Uganda and often leads to change in ways government operates against set policies and regulations. Likewise, current policies of decentralized management of resources, promotion of private sector participation, service delivery and increased need for stakeholder participation in environmental management, call for a change in the way water resources management functions are performed. While efforts are being put into addressing the above concerns, the current legal and institutional framework, and strategies for water resources management are inadequate to address all of them in an integrated manner. There is therefore a need for development of a policy framework that promotes a holistic approach to water resources management development in the country so as to ensure availability of water of adequate quantity and good quality for the present and future generation.

International involvement in water resources management

Currently, Uganda have participated in regional and international water resources management programmes and initiatives including; Lake Victoria Environmental Management Project (LVEMP), Lake Victoria Water Resources Project, the Inter-Governmental Authority for Development (IGAD), Nile Basin Initiative (NBI), the Lake Victoria Fisheries Organisation (LVFO) and Lake Victoria Development Programme. Such initiatives opportunistically call for a

transboundary water resources strategy that will guide Uganda's participation in regional water resources management initiatives and enable management apply acquired knowledge and skills to the local level. Majority of such initiatives have indeed been introduced and promoted for water bodies with large catchments and that serve a wider population.

Involvement at a local level

At a local level, structures of Beach Management Units, Integrated lake management organisations and other fisheries management committees through by-laws and District Fisheries management plans have been put up but these need to be regularised (Nakasongola District Council, 2008). For the case of Lake Kwania and Kyoga, Integrated Lake Management Organisation for Lake Kyoga (LAKIMO) is part of the initiatives under integrated water resource management zones in Uganda. However, activities of such an organisation need support through financial and technical assistance from the government if they are to achieve the goals set out. While central government will retain overall responsibility for water resources management, the management of these resources may require decentralisation. The Constitution, Local Government Act and the Water Statute specify the roles and responsibilities of the Central and Local Governments with respect to water resources management. In addition to decentralised water resource management, capacity building in local governments and district level institutions will be vital for achieving water resource management.

Legislation in water resource management

The current legislation include the Water Statute and National Environmental Statute both consisting of provisions relating to pollution control but do not provide adequate regulation for non-point sources of pollution and waste discharge to groundwater. In addition, the pollution standards in the Environmental Statute are considered by some to be too stringent, which makes them a disincentive to industrial development and thus need to be reviewed. Furthermore, regulations for the waste discharge, issuing of permits to industries, construction of hydraulic works and drilling works have been issued under the provisions of the Water Statute but challenges are being experienced in implementing and enforcing them. Additionally, the existing legal provisions concerning land use and ownership of water facilities need to be reviewed to ensure that all aspects of water rights are clearly well-defined and effectively safeguarded. Water rights to local governments, privately owned water facilities within water authority controlled service areas, the process of dispute resolution over water rights, and legislation governing catchment protection are areas that need to be addressed.

Initiatives through research

Planning a management strategy for water bodies requires research involvement in order for planned activities and implementation to have a scientific basis. Specifically, managing

pollution, eutrophication and outcomes such as invasive outgrowth of weeds such as *S. molesta* involves identification of the source, mapping the coverage of infestation, identification and minimising sources of nutrients entering the water body (van Oosterhout et al. 2006). The nutrient sources include; livestock handling areas, garden runoff, cropping and agriculture, erosion of cultivated land, urban sewage outflows and industrial wastewater among others. For the case of Lake Kyoga and minor lakes, gully erosion, wastes from human activities and livestock are the potential sources of nutrients (mainly phosphorus and nitrogen) into the lake (Burgis and Symoens 1987; FIRRI 2001). The generated wastes in Lake Kyoga catchment are untreated with high levels of pollutants like phosphates and nitrates (FTI 2004). These nutrients create favourable conditions for *Salvinia molesta* infestation of Lake Kyoga. However, there has been inadequate study and management of *S. molesta* weed on the Lake Kyoga minor lakes as evidenced by the outcry of the people in Lake Kyoga basin from *Salvinia* infestation with its devastating environmental and socio-economic impacts (Wanda et al. 2015). Hence an urgent intervention to control the noxious *S. molesta* weed not only in Lake Kyoga but also in other lakes such as Lake Albert is required so as to fully use and exploit the resources of the lake.

Case study: Lake Kwania

Through the Agricultural Technical and Advisory Services (ATAAS), government through NARO had some research interventions that involved mapping of the *S. molesta* infestation in order to direct management of the water resources. At selected landing sites of one of the Kyoga minor lakes (Lake Kwania), cover abundance of the weed was determined and some physico-chemical parameters that favour the multiplication of *S. molesta* in those areas investigated. High cover abundance (≥ 300 ha) was, at the point of sampling found at areas of Amai, Etam, Amuk and Adero in Amolatar (Figure 1), Agee, Agweng, Abebe, Madyaba and Ogwil in Apac, and Awei in Dokolo. Many of these areas included waste sites and boat docks. As there is poor waste management around African Great Lakes including Lake Kyoga, the high coverage of *S. molesta* is expected. Improper waste management can lead to proliferation of invasive species and it is worth noting that the boat dock area in Amai had the highest cover abundance.

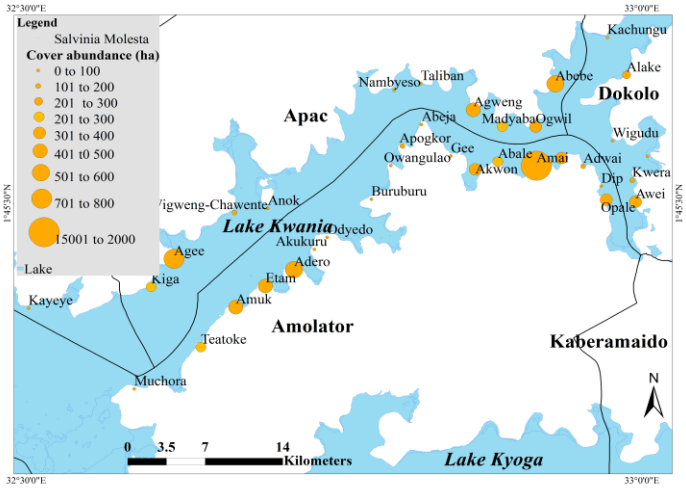


Figure 1: Cover abundance of *Salvinia molesta* along landing sites at Lake Kwania (obtained from Wanda et al. 2015).

Metal contamination issues are becoming increasingly common and cannot be ignored when it comes to managing the water environment. with many documented cases of metal toxicity in mining industries, foundries, smelters, coal-burning power plants and agriculture Investigations into sediment of the sites indeed revealed mainly fine silt and organic matter that gave the typical colouration of dark brown and black, associated with the characteristic appearance of Fe oxides. Fe and Mn were notably higher than permissible levels of fresh waters in Kachung. Deep in the sediment, the oxygen concentration also drops hence the lower redox states of Fe II and Mn II are favoured and according to Hamilton-Taylor and Davison, (1995), the ions are very soluble in the pH ranges of 4-8. All the other metals i.e. Cu and Zn that are either adsorbed or desorbed by the presence of Fe and Mn oxides or sediment particles were however below the maximum permissible levels in unpolluted freshwater lake sediment from freshwater lakes. Analysis of fish tissues revealed low concentrations of the most lethal metals Cu and Zn, lower than the maximum permissible WHO limits (Table 1.3). Although not investigated in this study, *Salviania molesta* has been reported elsewhere to absorb heavy metals from water through their shoots and roots (Sukumaran 2013, Kumari et al. 2017). This is advantageous in phytoremediation so that the heavy metals are kept at low concentrations in the water column. However, on decomposition these contaminants are released back into the water and eventually will have consequences on the biota. There is need for long term studies of heavy metal concentration in the lake and also the relationship between their concentration and cover abundance of *S. molesta* in the lake.

Table 1: Concentrations of selected heavy metals (µg/g) in water-sediment interface of Lake Kwania.

Site	Fe	Mn	Cu	Zn
Kachung	1.4	0.44	0.00	0.14
	40.8	5.38	0.07	1.28
	8.0	0.78	0.28	0.22
Abeja Nambyeso	0.0	0.0	0.0	0.04
	1.6	0.0	0.14	0.08
	0.5	0.0	0.16	0.06
Chawente Nambyeso	6.0	0.21	0.15	0.09
	0.0	0.01	0.01	0.04
	2.2	0.06	0.00	0.05
Apalamio	12.8	0.22	0.01	0.08
Kakoge	4.7	0.20	0.00	0.08
Freshwaters	<30	<5	1.8	0.5

Table 1.2: Concentrations of selected heavy metals (µg/g) in sediment of Lake Kwania.

Site	pH	Fe	Mn	Cu	Zn
Kachung	6.4	978.9	118.5	1.4	27.8
	6.8	975.5	209.6	0.0	48.4
	6.7	953.8	143.1	0.5	33.1
Nambyeso/Abeja	7.1	1222.9	101.6	1.5	23.9
	7.0	1031.9	169.8	0.8	39.3
	7.0	1073.6	148.9	1.7	34.5
Chawente/Nambyeso	5.8	999.5	60.1	1.6	14.4
	6.5	1073.0	79.0	0.6	18.6
	6.9	1123.4	61.2	1.9	14.6
Apalamio	6.8	1.9	0.0	0.0	0.5
Kikoge	6.2	923.1	36.7	1.8	8.9
Unpolluted Lake sediments (FAO 1996)		41000	770	33	95

Table 1.3. Concentration (µg/g dry wt) of selected Heavy metals in fish parts.

Site	Part	Fe	Mn	Cu	Zn
Abeja Nambieso	Gills	18.9	0	0	0.8
	Flesh and Skin	18.8	0	0	0.60
Kacung	Flesh and Skin	0	0	1.27	0.80
	Gills	165.4	0	1.77	0.93
Chawente Nambieso	Gills	57.1	0.04	1.18	1.35
	Flesh and Skin	0	0	0.59	0.86
Apalamio	Flesh and Skin	0	0	0	0.77
	Gills	74.5	12.3	0.8	4.2
Kikoge	Flesh and Skin	0	0.1	0.1	1.4
	Gills	17.6	0	1.01	1.24
WHO Limits		-	-	30	1000

Except Nitrogen (TN) which was generally high, all other selected physico-chemical parameters were significantly different between sites (Table 2), with a distinction between sites from the western region of the lake (Kayeyi and Apalamio) and those in the central (Nambyeso and Chawente) and Eastern region (Kachung). This finding is true for parameters such as conductivity where the least conductivity measurement was from the Western zone where the Nile joins the lake through Lake Kyoga hence diluting it with the Nile water whose conductivity is around 99 μScm^{-1}. Conductivity increased toward the Eastern side which experiences run off from the Elgon areas. Similar to Fe, Mn and Zn, Silica (SRRi) concentration an indicator of allochthonous loading from the catchment was highest at Kachung. However, Phosphorus (TP), was highest at Nambyeso, although Kayeyi which is closest to the Nile still had a much lower concentration.

Table 2: Descriptive statistics of selected physico-chemical parameters on Lake Kwania across different sampled sites. Not significant (p> 0.05); Min.: minimum; Max.: maximum; SE: Standard error of the mean. Differences in parameters with normally distributed data were tested using one-way ANOVA while Kruskal Wallis statistical test was used for the reverse. Silica (SRSi) values were log-transformed.

Parameter	Site	Min	Max	Mean±SE	p
pH	Kayeyi	7,32	8,59	8,19±0,2	0,03
	Apalamio	7,6	8,2	7,9±0,1	
	Nambyeso	5,7	8,4	7,6±0,1	
	Chawente	7,8	8,6	8,2±0,1	
	Kachung	7,3	8,61	8±0,1	
SpC μScm^{-1}	Kayeyi	121,6	132	126±2,7	0
	Apalamio	110,9	118,3	114,1±1,7	
	Nambyeso	215	242	228,4±1,7	
	Chawente	160,4	197,1	181,04±3,9	
	Kachung	239	302	278±4,3	
TN mgL^{-1}	Kayeyi	347,6	402,8	378,9±12	0,36
	Apalamio	309,7	378,6	344,1±19,9	
	Nambyeso	151	520	360,9±32,5	
	Chawente	282,1	668,3	455,5±44,5	
	Kachung	264,8	606,2	381±29,7	
TP mgL^{-1}	Kayeyi	72,3	73,9	73,3±0,4	0,041
	Apalamio	91,3	271,3	166,9±53,9	
	Nambyeso	74,75	738	204,9±72,2	
	Chawente	78,9	364,7	133±39,6	
	Kachung	72,3	304,7	120,9±22,2	
SRSi mgL^{-1}	Kayeyi	39,2	43,7	40,9±0,9	0
	Apalamio	11,8	23,8	18,7±3,6	
	Nambyeso	17,5	90,2	67,2±5,6	
	Chawente	46,3	67,6	55,4±2,4	
	Kachung	89,7	117,5	98,5±2,6	

Low cover abundance of *S. molesta* was found in areas with the Nile influence probably due to the Nile flow and thus lower water retention capacity compared to other areas. Areas in the central and Eastern region with higher water retention capacity thus high nutrients and ions were found to be in conditions that can support growth of Kariba weed (Cary and Weerts, 1984), with water temperatures between 20 and 30° C, tolerable pH range (7.5 – 8.3) and high nutrient conditions, especially Nitrogen and Phosphorus.

Purpose of the guidelines

To control or prevent further spread of *S. molesta* infestation is a key management objective in countries whose lakes are infested by *S. molesta*. These guidelines have been prepared as a contribution towards efforts to manage water environment of lakes, in order to control environmental factors that promote proliferation of *Salvinia molesta,* especially nutrients in Lake Kwania.

Operational actions

1. Increase efforts in research
    - Results from the case study revealed influence of the catchment on the lake. More research investigating various environment relationships should be encouraged in order to produce management guidelines with a scientific basis.
    - The Eastern part of the lake i.e. Kachung acts as a water abstraction point for drinking water for Lira town. This zone recorded high concentration of chemical elements that are usually detrimental to organisms along the food chain including fish and humans when the levels exceed permissible concentrations. Monitoring of these elements is advisable in order to save the integrity of the zone as a source of drinking water to the public.
    - Connection of the lake to the Nile calls for monitoring programmes to be set up around sites in the western region i.e. Kayeyi, Kakoge and/ or Apalamio in an effort to record daily or monthly data of the water chemistry and sample cover abundance of *Salvinia* to make sure that the infestation does not spread further within the Nile.

2. Controlling the weed

    - Nutrient management

        Given the shallowness of the lake, frequent nutrient recycling constantly carries nutrients to the water column and thus nutrients from the catchment cause excessive fertilisation of the lake which has effects on the biota of the lake. Weeds are a sign of eutrophication of systems and interventions to reduce nutrient loading into the lake will contribute to prevention of *Salvinia* proliferation.

        Lakes and rivers usually receive inputs of nutrients and sediment from the watershed as a result of natural runoff and soil erosion (Miller 1994). Concerns about weeds, such as *Salvinia molesta*, tend to arise when nutrient loading is exacerbated by human activities (Wetzel 1983). Nutrient inputs may become excessive because of agricultural runoff, failing septic systems, deforestation, building and road construction, and effluents from sewage treatment facilities. Management strategies to reduce nutrient inputs through informed land-use and conservation practices e.g., restoration and protection of buffer zones, use of advanced sewage treatment technologies, construction of landfills, diversion of animal wastes, strip cropping and contour farming, would help to improve water quality and reduce the potential for proliferation of *S. molesta*. Presence of a well-developed riparian wetland and littoral plant communities in Lake Kwania and other lakes could intercept excess nutrients before they accumulate and promote the excessive growth of problematic species (Mitsch and Gosselink 1993).

- Early detection should be undertaken in catchments at risk from *Salvinia* invasion, especially after floods because this is one way it spreads to new areas.
  Manual removal of *Salvinia* has the advantage of removing nutrients from the water, in comparison to herbicide control in which the nutrients from dead *Salvinia* are released into the water, potentially affecting water quality, increasing nutrient availability and thus *Salvinia* growth. This strategy is however possible for controlling small infestations. However, for large ones, biological control with the weevil *Cyrtobagous salviniae* is reportedly very effective in warm temperate, tropical or sub-tropical climates, providing successful control. This method is the most cost-effective and environmentally friendly technique for the sustainable control of weeds.
- Mechanical and chemical control techniques should be integrated to manage large *Salvinia* infestations where biological control is less effective.
- Training requirements; People to undertake biological or chemical control methods should have proper training in the use of the chemical/biological agents. Furthermore, they must have a strategic plan in place over several years to ensure that the process is successful and the system doesn't relapse into an infestation state.

3. Integration of management programmes

- Integrate the management of *Salvinia molesta* with broader land management programs designed to reduce the amount of suspended sediment and nutrient run-off entering Lake Kwania.
- There should be policies that govern importation and use of alien species in Ugandan water bodies.
- Target awareness campaigns at landholders in areas at risk of invasion such as Amai so that they can recognize *Salvinia molesta* and prevent its spread.

4. Public awareness
   - Raise awareness so that the public is informed about actions that bring about water quality deterioration.
   - Management of nutrients is key in controlling the weed. Agricultural run-off, sewage, storm water and erosion runoff are the main preventable forms of nutrient input that could be targeted for control of *Salvinia*.
   - Inform the public about *Salvinia molesta* and its impacts on the ecosystem. Preventing *Salvinia'*s spread will only be achieved by educating the public, as it is most commonly spread (either deliberately or accidentally) by people (see plate 2).
   - Researchers or authorities should educate the public about mechanisms for disposal of *Salvinia molesta*, i.e. who are cultivating it or using it in aquaculture operations. In Australia, burning, drying in the sun and/or use as garden mulch have been found suitable.

- The sale or dumping of the weed should be reported to the authorities, and people who have unknowingly cultivated it should contact local councils or state/territory weed management agencies for information on how to properly dispose of *Salvinia*.
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5. Commitment
   - Enforce compliance when landowners do not take reasonable steps to control *Salvinia molesta*.

6. Consultation and partnership
   - Build working partnerships between key stakeholders to generate a holistic approach to the management of water environment and a sense of community ownership of prevent spread of *Salvinia* weed.
7. Planning
   - Map the extremities of infestation of *Salvinia molesta*.
   - Monitor areas potentially at risk of new infestations.
   - Ensure that management plans for *Salvinia molesta* are consistent with plans in neighbouring countries.
   - Secure adequate resources (i.e. time, funds and personnel) to carry out actions for instance in these guidelines.

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