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Mapping of Flood-Prone Areas and Assessment of Water Resources at the Tongon Site (M'Bengue, Northern Côte d'Ivoire): Implications for the Siting of a Photovoltaic Power Plant

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Abstract

This study maps flood-prone areas and assesses the water resources of the Tongon site (M'Bengue department, northern Cote d'Ivoire), proposed for a 30 MWp solar photovoltaic (PV) power plant. We combined a hydrological and hydrogeological field campaign (May 2022) with climate records from the Korhogo synoptic station (2016-2021), borehole data from the National Office of Drinking Water (NODW), and pedological and geotechnical surveys by the LABOGEM consultancy. A flood-risk map was produced by multicriteria analysis, crossing a hazard map with a vulnerability map. Flood risk is low to moderate and confined to the banks of the Katie River, whose August-September floods reach 16 cm of water at the site boundary. The measured low-flow discharge of the Katie is 1.912 L/s (6.88 m^3/h). The available water resources (rainwater, surface water, and groundwater from the weathered regolith and bedrock fractures) amount to 65,551,120 L/year, far above the plant's requirements of 740,000 L/year. The waters, however, are contaminated by arsenic, most likely of natural origin (arsenopyrite), and need treatment before any domestic use. We recommend a drainage channel to intercept floodwater and divert it to the Katie River to secure the plant.

Keywords

Flooding, Multicriteria Analysis, Water Resources, Hard-Rock Aquifer, Arsenic, Photovoltaic Power Plant, Côte d'Ivoire

1. Introduction

Energy demand is growing fast in sub-Saharan Africa, and renewable energies, solar photovoltaics in particular, are expected to supply much of it [1]. In Cote d'Ivoire, the State has launched a program to diversify the electricity mix with solar energy. Each candidate site must first be characterized, especially for natural hazards and water availability, which matters for construction, panel cleaning, and the base camp [2]. Flooding by overflowing rivers is among the most damaging hazards in West Africa, and mapping it is a prerequisite for any development [3] [4].

In the crystalline and crystalline-phyllitic basement terrains of northern Cote d'Ivoire, groundwater is closely tied to lateritic weathering profiles and fractured zones, as described in the conceptual model of stratiform, multilayer hard-rock aquifers [5] [6]. Borehole yields there depend on regolith thickness and the degree of fracturing [7] [8]. The Tongon area also hosts a large open-pit gold mine, whose activities raise questions about water quality, in particular arsenic associated with the sulfide mineralization (arsenopyrite, pyrite, pyrrhotite) [9].

In this context, the present work aims to 1) identify and map the flood-risk zones of the Tongon site; 2) estimate the discharges and flood levels of the site's main watercourse; 3) identify and quantify the water sources available for the construction and operation of the 30 MWp photovoltaic power plant; and 4) check these resources against the applicable guidelines. The originality of the approach lies in combining a multicriteria flood-risk analysis at the scale of a basement subcatchment with a quantitative and qualitative water balance from three sources (meteoric water, surface water, and groundwater) for a solar power plant in a mining area.

2. Study Area, Materials, and Data

2.1. Study Area

The Tongon site lies in the M'Bengue department (Poro region), northern Cote d'Ivoire, just south of the Tongon gold mine, within the Bandama River basin. The Katie River borders the site; the mine has built a water reservoir on it, with a 48.1 km perimeter covering about 11 km^2, for its industrial needs. The relief is semi-accidented, made of rolling plateaus between 300 and 400 m elevation, interspersed with iron-capped hills (bowe) and granitic ridges. The climate is tropical of the Sudanese-Guinean type, with a rainy season from May to October and a dry season from November to April, marked by the harmattan from December to February. Over 2016-2021, annual rainfall at the Korhogo synoptic station, the most representative of the site, ranged from 658 mm to 1452 mm, with a mean of 1055 mm. Mean monthly temperature varies from 24.7 degrees C (August) to 29.5 degrees C (March-April). The calculated mean annual evaporation is 1653.4 mm, peaking in January (255 mm) under the harmattan. Mean relative humidity ranges from 31% (December-January) to 77% (June-September), and the dominant winds, driven by the monsoon, are southwesterly at 3.1 to 5 m/s.

The site geology consists of outcrops of medium-grained biotite granites, locally associated with green rocks (schists, quartzites, manganese-bearing rocks) and with concordant granitoids and basic plutonites. The weathering profile, revealed by hand-auger borings (down to 4 m, or refusal between 0.20 and 3.80 m) and by the pressuremeter borings SP1 to SP10 (12 m deep) carried out by LABOGEM, shows from top to bottom: a thin humiferous soil, a layer of gravelly and lateritic clays (sandy clay, lateritic gravel, lateritic clay in brown, grayish, yellowish, or reddish shades), 1.40 to 3.10 m thick, and then weathering clays over the whole tested depth.

2.2. Materials and Instruments

The field surveys used: 1) a differential GNSS receiver to position the measurement points, site boundaries, and sampling points; 2) a current meter for discharge measurements in the Katie River; 3) a field multiparameter probe (electrical conductivity, pH, temperature) for in situ hydrochemical characterization; 4) a handheld GPS and a flood-stage chart to record observed water levels; and 5) a geographic information system (QGIS/ArcGIS) coupled with remote-sensing data (multi-date satellite images and a digital elevation model) for the spatial analyses. Statistical and cartographic processing was done in QGIS, Excel, and the HYFRAN software [10] for frequency analyses.

2.3. Data

Four categories of data were used:

- climate data (2016-2021) from the Korhogo synoptic station [11]: rainfall, maximum and minimum temperatures, evaporation, relative humidity, and the 2021 wind rose;
- hydrogeological data from the ONEP [12] on the abstraction works of the Tongon locality (total depths and depth to bedrock, static water levels, exploitable discharges, coordinates), completed by the LABOGEM geotechnical borings (hand auger and pressure meter tests);
- water-quality data: arsenic concentrations (2013-2016) in the surface and groundwaters of the mine and the riparian villages [9];
- field data from the hydrological and hydrogeological campaign of 10-14 May 2022: discharges, flood levels, resurgence points, conductivities, photographs, and testimonies of the riparian populations.

3. Methods

3.1. Flood-Risk Mapping by Multicriteria Analysis

The flood-risk assessment followed the classical hazard x vulnerability framework [3] [13]. First, thematic maps of the Katie sub-catchment were produced from the DEM, land cover, distance to the drainage network, pedology, and rainfall: slope, drainage density, contour lines, distance to watercourses, soil types, and land-cover classes. Each thematic map was classified and weighted, and their weighted

arithmetic combination gave the hazard map, using an AHP-type multicriteria analysis already applied with success in West Africa [4] [14].

Second, the vulnerability map was drawn from the existing and planned stakes (footprint of the site, access infrastructures and bridge, settlements, and agricultural activities). Multiplying the hazard map by the vulnerability map gave the flood-risk map, classified into four levels (low, moderate, high, very high). The map was validated against the field observations of the May 2022 campaign (areas actually flooded in August-September, water levels reached, condition of the downstream bridge of the mine) and the testimonies of riparian populations [15].

3.2. Discharge Measurements and Flood Estimation

The discharge of the Katie River was measured at low flow (May 2022) at the Tongon bridge by the velocity-area method: the cross-section was divided into verticals, velocity was measured with the current meter, and the elementary discharges were integrated. The maximum flood level was recorded from flood marks and testimonies (16 cm at the site boundary). The annual volume was first approximated by

$$V = Q \times t \tag{1}$$

with $t = 24 \times 365$ h, assuming a regime close to the measured one. This is a conservative assumption, given the strong seasonality of Sudanese-Guinean regimes [16] [17]. The frequency analyses of regional floods followed the approaches of daily flood regional analysis [18] [19] and the WMO manuals for low flows [20].

3.3. Quantification of the Water Resources

3.3.1. Meteoric Water (Rainwater Harvesting)

The volume recoverable from a corrugated roof was estimated by the classical collection formula:

$$V = P \times S \times Cp \tag{2}$$

where P is the rainfall (mm), S the collecting area (50 m^2), and Cp the roof loss coefficient (0.8). The computation was repeated for the maximum (1452 mm), mean (1055 mm), and minimum (658 mm) rainfall, in line with stormwater management guidelines [21].

3.3.2. Surface Water

The potential of the Katie River was assessed from the measured discharge, extrapolated to an annual volume, and compared with the competing uses (an identified agricultural pumping of 60 m^3/h). The feasibility of a hillside reservoir of the type built by the mine was examined against the needs of the plant (panel cleaning and related uses).

3.3.3. Groundwater

The hydrogeology of the area was characterized according to the conceptual model of hard-rock aquifers [5] [6]: an unconfined aquifer in the regolith (10 - 45 m)

overlying a deep fractured aquifer. The parameters came from the ONEP borehole records (static level, exploitable discharge, total depth, depth to bedrock) and from the LABOGEM borings (regolith thickness, static water level, test discharges). Discharges were converted into annual volumes ($Q \times 24 \times 365$) and compared with the project's needs.

3.4. Water-Quality Assessment

The arsenic contents measured by Affoun [9] over 2013-2016 in the surface waters (RW and SW points) and groundwaters (TGW and GW points) of the mine and the villages were compared with the WHO guideline for drinking water [22] (10 ug/L, *i.e.*, 0.01 ppm) and with the IFC environmental guideline for effluents and surface waters [23] (0.1 ppm). The interpretation separated the anthropogenic origin (mining activities, management of waste rock and effluents) from the natural origin (arsenopyrite of the deposit), based on the mine/village comparison and the absence of a marked temporal trend [9].

3.5. Needs-Resources Balance

The water requirements of the plant, estimated by the developer at 740 m^3/year for the construction and operation phases, were compared with the sum of the annualized resources (recoverable meteoric water, annual volume of the Katie, exploitable volumes of the boreholes) to establish the availability balance of the resource.

4. Results

4.1. Climatic Setting and Station Statistics

The climate statistics of 2016-2021 reflect the Sudanese-Guinean regime of the site: the amplitude of the mean maximum temperatures (3.3 degrees C) exceeds that of the minima. Evaporation is highest in the dry season (>200 mm/month from January to March) and lowest in the rainy season (<80 mm/month from August to September) (Table 1 and Table 2).

Table 1. Mean monthly temperatures at the Korhogo synoptic station (2016-2021) [11].

Parameter (˚C)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Mean maximum	33.9	35.9	35.8	34.5	32.5	30.9	29.4	29.3	30.0	31.8	33.4	33.4
Mean minimum	18.7	21.1	22.6	22.9	22.2	21.1	20.8	21.1	20.6	20.8	20.1	18.4
Mean	26.7	29.0	29.5	28.8	27.6	26.0	24.9	24.7	24.9	26.0	26.8	26.2

Table 2. Mean monthly evaporation (mm) at Korhogo (2016-2021) [11].

Month	Jan	Feb	Mar	Apr	May	Jul	Aug	Sep	Oct-Dec
Evaporation (mm)	255.0	239.5	216.6	146.6	110.7	67.3	56.8	55.7	426.0
Annual total	1653.4								

4.2. Flood-Prone Areas

The combination of the thematic maps (slope, drainage, pedology, land cover, rainfall) produced the hazard and vulnerability maps, whose crossing gives the flood-risk map of the Katie sub-catchment. The project site falls in a low to moderate flood-risk zone. The areas that can be flooded are the banks of the Katie River, which borders the site, in August and September: the river overflows into the plain downstream of the mine, and the bridge downstream of the Tongon gold mine is regularly submerged (field observation and testimonies of the riparian population). When the river leaves its bed, the water depth can reach 16 cm at the site boundary. This may hinder access during construction and operation, but it does not threaten the main layout of the plant. The discharge measurement of May 2022 gives a low flow of 1.912 L/s (6.88 m^3/h) at the Tongon bridge, hence an annual volume of about 60,268,800 L (extrapolated over 24 × 365 h). A resurgence was recorded on the site, with conductivity measurements confirming the groundwater-river interaction. The mine reservoir (48.1 km perimeter; 11 km^2) shows the storage potential of the watercourse (Figures 1-3).

Figure 1. Discharge measurement of the Katié River at Tongon (May 2022).

Figure 2. Resurgence zone and conductivity measurement at Tongon (May 2022).

Figure 3. View of the reservoir of the Tongon mine (impoundment on the Katié River) (May 2022).

4.3. Mobilizable Water Resources

4.3.1. Meteoric Water

For a 50 m^2 roof with a loss coefficient of 0.8, the recoverable volume varies from 26.3 m^3 (dry year) to 58.1 m^3 (wet year), *i.e.*, 42.2 m^3 for the mean year (Table 3).

Table 3. Recoverable rainwater volume (50 m^2 roof, Cp = 0.8).

Rainfall scenario	Rainfall (mm)	Recoverable volume
Wet year	1452	58,080 L (58 m^3)
Mean year	1055	42,200 L (42 m^3)
Dry year	658	26,320 L (26 m^3)

4.3.2. Surface Water

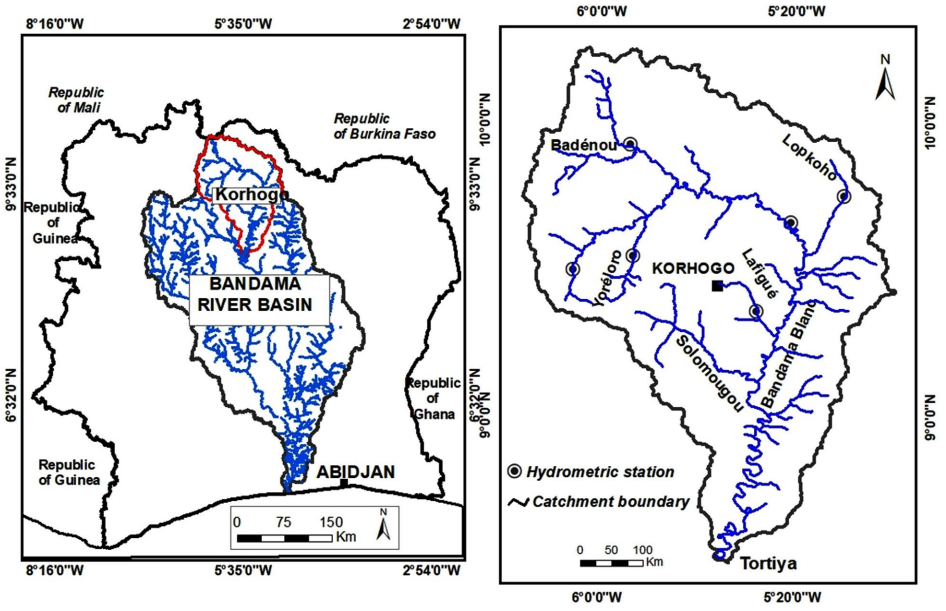

Figure 4. Generalized drainage network of the Bandama basin.

The local hydrography is dominated by the Bandama and its tributaries, including the Katié. The extrapolated annual volume of the Katié (60.3 million liters) easily covers the industrial needs of the plant (panel cleaning and related uses); an agricultural pumping of 60 m^3/h already exists on the watercourse. A hillside reservoir modeled on the mine's appears technically feasible (Figure 4 and Figure 5).

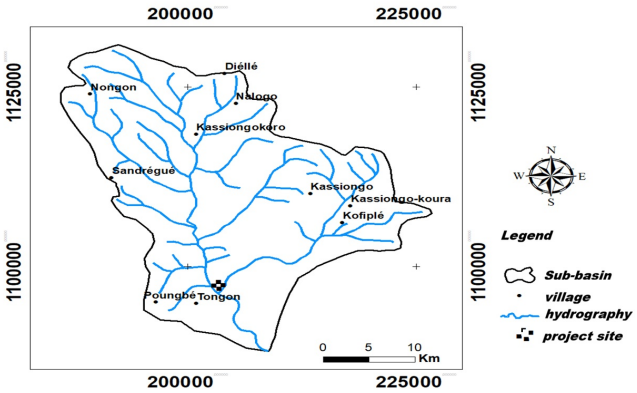

Figure 5. Local hydrography of the Tongon site.

4.3.3. Groundwater

Two aquifers coexist: 1) the unconfined regolith aquifer, the most important, between 10 and 45 m depth, with a static water level encountered between 1.50 and 10.50 m during the LABOGEM borings (June 2022); and 2) a deep fractured aquifer, poorly developed but present in the mineralization zone, with levels from 2 to 26 m for discharges of 0.03 to 2.5 L/s. In the regolith, the mean depth is 38 m with a static level at 4.1 m and mean borehole discharges of about 1.94 m^3/h; in migmatites, the regolith reaches 52 m depth with a static level at 12.3 m, and the boreholes do not dry out in the dry season. The two exploited boreholes of the locality [12] have static water levels of 28.6 m and 24.5 m and exploitable discharges of 0.60 m^3/h (5,256,000 L/year) and 1.20 m^3/h, for total depths of 61 m and 68.3 m (Table 4). The regolith boreholes tend to dry out in the dry season and recharge during the rainy season (Figure 6).

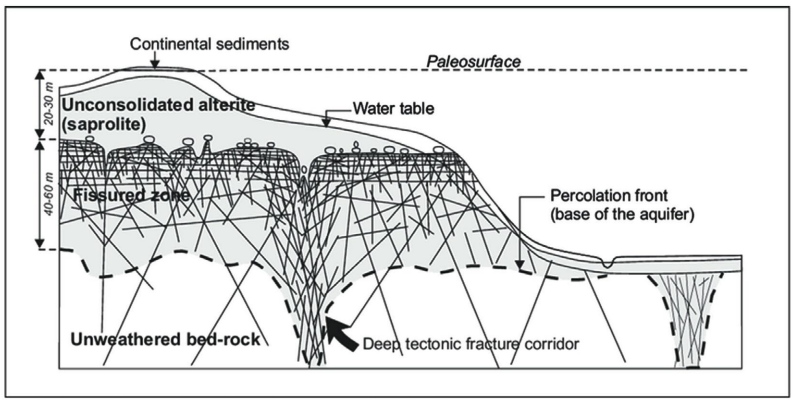

Figure 6. Conceptual model of a hard-rock aquifer: stratiform, multilayer aquifer linked to former lateritic weathering profiles [5].

Table 4. Characteristics of the exploited boreholes at Tongon [12].

Village	Works	Total depth (m)	Depth to bedrock (m)	Static level (m)	Discharge (m^3/h)	Status
Tongon	Borehole	61.0	44.0	28.6	0.60	Exploited
Tongon	Borehole	68.3	38.3	24.5	1.20	Exploited

4.3.4. Water Quality (Arsenic)

In the surface waters of the mine, mean annual arsenic concentrations frequently exceed the IFC guideline (0.1 ppm), notably at points RW01 (2.25 ppm in 2013; 1.00 ppm in 2016) and RW02 (0.158 ppm in 2016); in the surface waters of the villages, contents reach 0.335 ppm (SW13, 2016) (Table 5). In the groundwaters of the mine, several exceedances of the WHO recommendation (0.01 ppm) are recorded (TGW13: 0.438 ppm in 2014; TGW29: 0.795 ppm in 2014; TGW28: 0.226 ppm in 2015), while the village piezometers (GW02, GW10) show occasional exceedances in 2013 without a clear temporal trend (Table 6). The absence of a temporal gradient linked to the mining operation suggests a contamination of natural origin related to arsenopyrite, possibly aggravated at the surface by the management of waste rock and effluent treatment [9].

Table 5. Mean arsenic concentrations (ppm) in surface waters [9].

Point	2013	2014	2015	2016
RW01 (mine)	2.25	3.00	1.313	1.004
RW02 (mine)	0.086	0.012	0.023	0.158
SW04 (mine)	0.057	0.004	0.009	0.258
SW12 (mine)	0.017	0.002	0.004	0.150
SW13 (village)	0.079	0.169	0.088	0.335
SW15 (village)	0.049	0.106	0.059	0.240
SW21 (village)	0.046	0.008	0.007	0.105

Table 6. Arsenic concentrations (ppm) in groundwaters [9].

Point	2013	2014	2015	2016
TGW13 (mine)	0.026	0.438	0.104	0.087
TGW35 (mine)	0.104	0.001	0.000	0.000
TGW29 (mine)	0.059	0.795	0.006	0.027
TGW28 (mine)	0.010	0.009	0.226	0.028
TGW10 (mine)	0.008	0.092	0.000	0.003
GW02 (village)	0.097	0.005	-	0.020
GW10 (village)	0.016	0.005	-	0.000

4.4. Needs-Resources Balance

The water requirements of the plant are estimated at 740,000 L/year. The annual-

ized resources total 65,551,120 L/year: 26,320 L of meteoric water (dry year, 50 m^2 roof), 60,268,800 L of surface water (Katie), and 5,256,000 L of groundwater (minimum discharge of the first borehole). The resources-to-needs ratio is therefore about 89, a very largely surplus availability (Table 7).

Table 7. Comparison of the available annual reserves with the annual water requirements of the plant.

Available annual reserves (L)	Annual requirements (L)
Meteoric water: 26,320; Surface water: 60,268,800; Groundwater: 5,256,000—Total: 65,551,120	740,000

Note: the discharges of the Katié and of the boreholes were converted into annual volumes (multiplication by 24 × 365).

5. Discussion

The flood-risk map obtained by crossing hazard x vulnerability is consistent with the multicriteria and GIS approaches applied in West Africa and in Cote d'Ivoire, where flood-prone zones concentrate in the lowlands and along the immediate banks of low-gradient watercourses [3] [4]. The classification of the site as low to moderate risk, with limited submersions (16 cm) confined to the banks of the Katié in August-September, agrees with regional studies on the flood dynamics of the Bandama tributaries. The agreement between the mapping and the field observations (submerged bridge, photographed flooded areas) validates the weighting retained. A complementary validation by 1D/2D hydraulic modeling (e.g., HEC-RAS) coupled with frequency analyses of the floods [17]-[19] would allow the quantification of the return periods of the submersions and the dimensioning of the protection works.

From a quantitative point of view, the extrapolation of the low-flow discharge over the whole year is a simplifying hypothesis. The regime of the Katié, highly seasonal like that of the Sudanese-Guinean watercourses, is marked by August-September floods and prolonged low flows. The volume actually mobilizable in the dry season, when panel cleaning is most needed (dust deposits are maximized by the harmattan), is therefore probably lower than the theoretical annual volume. A hillside reservoir, already proven by the mine on the same watercourse, then appears the most robust solution, subject to a storage-capacity study of the site and an assessment of the impact on downstream uses (irrigation).

The groundwaters confirm the hard-rock aquifer model: productivity linked to the thickness of the regolith (38 to 52 m) and to the fractured zones, deep static levels in zones of weakly weathered basement (24.5 to 28.6 m), and seasonal drying of the shallow works, in accordance with the syntheses [6] and the statistics of borehole yields in weathered zones [7] [8]. The combined exploitable discharge of the existing boreholes (1.8 m^3/h) is enough to cover the needs of the plant (0.085 L/s on average), but combining the three sources remains the recommended option to secure the supply, especially at the end of the dry season.

Arsenic contamination is the main limiting factor for the use of local waters. The recurrent exceedances of the WHO standard in the groundwaters and of the IFC guideline in the surface waters, without a temporal gradient linked to the mining operation, point to a geogenic origin (arsenopyrite). This phenomenon is widely documented in the Birimian belts of West Africa, even if mining activities can locally aggravate the mobilization of arsenic through the management of waste rock and effluents [9]. Any use of the Tongon waters for human consumption will therefore require appropriate treatment (oxidation, coagulation/filtration, adsorption on activated alumina or zero-valent iron) and regular analytical monitoring of arsenic, in accordance with the WHO [22] and IFC [23] guidelines.

The limitations of the study are: 1) the short duration of the measurement campaign (low flow only); 2) the extrapolation of the measured discharges; 3) the choice of the Korhogo station as a climatic proxy for the site; and 4) the relative age of the quality data (2013-2016). Complementary campaigns (high flows, repeated gaugings, seasonal piezometry, updated physico-chemical and bacteriological analyses) and the installation of a rain gauge and a staff gauge on site would strengthen the diagnosis, within a monitoring program adapted to climate change [24].

6. Conclusion

The hydrological and hydrogeological study of the Tongon site leads to three main conclusions. First, the site of the photovoltaic power plant is not directly threatened: the flood risk is low to moderate and limited to the banks of the Katié River during the August-September floods, with a water depth of up to 16 cm at the site boundary. A drainage channel on the periphery of the plant, to trap and evacuate floodwater to the Katié, is enough to secure the installations and access. Second, the water resources of the site, *i.e.*, recoverable meteoric water, the surface water of the Katié, and the groundwater of the regolith and basement fractures, total about 65.55 million liters per year, far above the estimated requirements of the plant (740,000 L/year). Supply can therefore come from complementary sources, with the option of a hillside reservoir for industrial uses. Third, the contamination of the surface and groundwaters by arsenic, very likely of natural origin (arsenopyrite), requires systematic physico-chemical analyses and appropriate treatment before any domestic use. These results give decision-makers and bidders the hydrological elements needed to design, protect, and operate the Tongon solar power plant.

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Author Contributions

Conceptualization, methodology, field campaign, data acquisition and analysis

(flood-risk mapping, discharge measurements, water-resources balance), original draft preparation, and final approval: B.K.Y.; field data collection (discharge and piezometric surveys, conductivity measurements, GPS positioning), contribution to hydrogeological data processing and thematic and flood-risk mapping, contribution to the interpretation of the results, critical review, and final approval: K.A. All authors have read and agreed to the published version of the manuscript.

Conflicts of Interest

The authors declare no conflict of interest. The study was carried out within the framework of a consulting mission funded by the Tongon photovoltaic power plant project; however, the results presented and the conclusions drawn are those of the authors, who guarantee the scientific independence and objectivity of the study.

References

[1] IEA (2023) Africa Energy Outlook 2023. International Energy Agency. https://www.iea.org/reports/africa-energy-outlook-2023

[2] Abuzaid, H., Awad, M. and Shamayleh, A. (2024) Photovoltaic Modules' Cleaning Method Selection for the MENA Region. *Sustainability*, **16**, Article 9331. https://doi.org/10.3390/su16219331

[3] Sy, B., Mbow, M. and Aw, S. (2025) Cartographie de la susceptibilité d'inondation, basée sur l'Analyse Hiérarchique des Procédés (AHP) dans les départements de Pikine et de Keur Massar, Sénégal. *VertigO*, **25**. https://doi.org/10.4000/15erk

[4] Kouadio, B.H., Oulare, S., Boka, K.C., Miessan, A.G. and Biemi, J. (2023) Cartographie des zones à risque d'inondation par débordement des cours d'eau dans la région semi-montagneuse de Man (Côte d'Ivoire): Approche par télédétection et analyse multicritère. *International Journal of Advanced Research*, **11**, 116-134.

[5] Lachassagne, P., Dewandel, B. and Wyns, R. (2014) The Conceptual Model of Weathered Hard Rock Aquifers and Its Practical Applications. *IAH—Selected Papers on Hydrogeology*, CRC Press, 13-45. https://doi.org/10.1201/b17016-3

[6] Lachassagne, P., Dewandel, B. and Wyns, R. (2021) Hydrogeology of Weathered Crystalline/Hard-Rock Aquifers—Guidelines for the Operational Survey and Management of Their Groundwater Resources. *Hydrogeology Journal*, **29**, 2561-2594.

[7] Bianchi, M., Diaw, M.T., Faye, S. and Lachassagne, P. (2023) Assessing Regional Variation in Yield from Weathered Basement Aquifers in West Africa and Modelling Their Future Groundwater Development and Sustainability. *Hydrogeology Journal*, **31**, 257-274. https://doi.org/10.1007/s10040-023-02594-w

[8] Aoulou, K.A., Pistre, S., Oga, Y.M.S., Dewandel, B. and Lachassagne, P. (2021) Improving the Methods for Processing Hard Rock Aquifers Boreholes' Databases. Application to the Hydrodynamic Characterization of Metamorphic Aquifers from Western Côte d'Ivoire. *Water*, **13**, Article 3219. https://doi.org/10.3390/w13223219

[9] Affoun, S.C.A. (2016) Suivi et évaluation de la concentration en arsenic dans les ressources en eau de la mine d'or de Tongon et ses environs. Master's Thesis, Institut International d'Ingénierie de l'Eau et de l'Environnement (2iE), 64 p.

[10] Bobée, B., *et al.* (2008) HYFRAN 2.2—Logiciel d'hydrologie statistique; Chaire en

hydrologie statistique CRSNG/Hydro-Québec, INRS-Eau, Terre et Environnement, Université du Québec.

[11] SODEXAM (2021) Données climatologiques de la station synoptique de Korhogo (2016-2021). Société d'Exploitation et de Développement Aéroportuaire, Aéronautique et Météorologique.

[12] ONEP (2022) Base de données des points d'eau du département de M'Bengué: Caractéristiques des forages de Tongon. Office National de l'Eau Potable.

[13] Merz, B., Kreibich, H., Schwarze, R. and Thieken, A. (2010) Review Article "Assessment of Economic Flood Damage". *Natural Hazards and Earth System Sciences*, **10**, 1697-1724. https://doi.org/10.5194/nhess-10-1697-2010

[14] Kangah, A. and Coulibaly, K.A. (2024) Application de la géomatique et de l'analyse multicritère à l'analyse du risque d'inondation dans la ville d'Agboville (Sud de la Côte d'Ivoire). *European Scientific Journal, ESJ*, **20**, 87-110. https://doi.org/10.19044/esj.2024.v20n23p87

[15] Nka, B.N., Oudin, L., Karambiri, H., Paturel, J.E. and Ribstein, P. (2015) Trends in Floods in West Africa: Analysis Based on 11 Catchments in the Region. *Hydrology and Earth System Sciences*, **19**, 4707-4719. https://doi.org/10.5194/hess-19-4707-2015

[16] Anctil, F., Rousselle, J. and Lauzon, N. (2006) Hydrologie: Cheminements de l'Eau. Presses internationales Polytechnique, 317 p.

[17] Meylan, P., Favre, A.C. and Musy, A. (2008) Hydrologie Fréquentielle: Une Science Prédictive. Presses polytechniques et universitaires romandes, 173 p. https://books.google.ci/books/about/Hydrologie_fr%C3%A9quentielle.html?id=R6Q3hQ1MtYYC&redir_esc=y

[18] Anctil, F., Martel, N. and Hoang, V.D. (1998) Analyse régionale des crues journalières de la province de Québec. *Canadian Journal of Civil Engineering*, **25**, 360-369. https://doi.org/10.1139/l97-124

[19] Ouarda, T.B.M.J., Girard, C., Cavadias, G.S. and Bobée, B. (2001) Regional Flood Frequency Estimation with Canonical Correlation Analysis. *Journal of Hydrology*, **254**, 157-173. https://doi.org/10.1016/s0022-1694(01)00488-7

[20] WMO (2008) Manual on Low-Flow Estimation and Prediction; Operational Hydrology Report No. 50. World Meteorological Organization, 136 p.

[21] MDDDELCC (2011) Guide de Gestion des Eaux Pluviales. MDDDELCC, 386 p.

[22] WHO (2017) Guidelines for Drinking-Water Quality, 4th Edition, Incorporating the First Addendum. World Health Organization, 631 p. https://www.who.int/publications/i/item/9789241549950

[23] IFC (2007) Environmental, Health, and Safety Guidelines—General EHS Guidelines. International Finance Corporation, 115 p. https://www.ifc.org/en/insights-reports/2000/general-environmental-health-and-safety-guidelines

[24] IPCC (2021) Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the IPCC. Cambridge University Press, 3949 p.