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SUBDIVISION PLAN AND STORMWATER DRAINAGE NETWORK FOR AN INFORMAL SETTLEMENT: THE CASE OF SOUSSONOUBOUGOU, BOUAKE (CÔTE D'IVOIRE)

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ABSTRACT

Informal settlements in sub-Saharan Africa often lack infrastructure, and upgrading programmes rarely integrate household sanitation assessment, spatial planning and drainage-flow estimation. This study combines these components in Soussonoubougou, a 49-ha neighbourhood of Bouaké, Côte d'Ivoire. A survey of 350 households conducted in August 2021 found that 67% relied exclusively on wells and 29% used wells alongside rainwater. Stormwater was mainly managed by natural infiltration (65%); where an outlet existed, it was usually the street (92%). Informal dumping was reported by 48% of households, pit emptying was manual in 65% of cases, and 71% of households that had emptied a pit did not know where the sludge was discharged. Using GPS observations, a digital terrain model and CAD/GIS tools, the urban plan was adapted to existing buildings and topography. The proposal includes 600-m^2 plots, roads of 25, 15 and 10 m, and reserved public-facility plots, and no subdivision of the flood-prone low-lying outlet area in the south. Eighty-four sub-catchments covering 44 ha were delineated from the proposed road and block layout and combined in series and parallel using the Caquot surface method for a 5-year return period. Calculations at 75 nodes and seven outlets produced elementary peak flows of 0.05–1.38 m^3/s and a peak flow of about 8.2 m^3/s for the 25.7-ha northern collector. The approach provides a practical basis for drainage design, but primary collectors require a 10-year check, and runoff coefficients, relocation needs, solid-waste management and sludge disposal require further assessment.

Keywords: Informal Settlement; Subdivision Plan; Stormwater Drainage; Caquot Method; Bouaké

1 INTRODUCTION

Urban growth is a rapid and irreversible global process, driven by the attraction of cities for rural populations seeking jobs, income and access to basic services, as well as by natural population growth [1]. Developing countries now accommodate the largest number of urban residents [2], and the number of people living in slums increased from a baseline of 650 million in 1990 to approximately 863 million in 2012 [38]. Although the situation has stabilised or improved in some regions, it remains alarming in sub-Saharan Africa, which lags behind the rest of the world in achieving the sanitation targets of the Millennium Development Goals [1,4].

Côte d'Ivoire follows this trend. The population of Bouaké, in the centre of the country, increased from 461,617 in 1998 to 536,189 in 2014 [5]. To give the city fresh impetus, the Government commissioned a Master Urban Plan (SDU) to 2030 [6], which is being implemented through detailed urban plans (PUd) under the Urban Infrastructure and Competitiveness of Secondary Cities Project (PIDUCAS) [7]. Nevertheless, many neighbourhoods in Bouaké combine a lack of sanitation, high population density, overcrowded housing and recurrent flooding, and the literature has described the causes and consequences of such precarious conditions [8]. Few studies, however, have combined a household-level sanitation assessment with an explicit spatial restructuring plan and an estimate of the stormwater flows that the new layout must convey.

Soussonoubougou, located near industrial areas and crossed by a railway line, is one such neighbourhood. This study aimed to propose a subdivision plan and a stormwater collection network for the neighbourhood. The specific objectives were to (i) assess the current state of water supply, drainage and sanitation; (ii) restructure the neighbourhood, where restructuring is understood as a major alteration to the road layout and built fabric of a large urban area, including road and network works and new facilities [9,10]; and (iii) estimate the peak stormwater flows to be conveyed.

2 MATERIALS AND METHODS

2.1 Location of the study area

Bouaké is located in central Côte d'Ivoire. The Soussonoubougou neighbourhood lies within the central belt of Bouaké. It covers approximately 49 ha and is located between latitudes 7°41′–7°43′ N and longitudes 5°02′–5°03′ W (Figure 1). Soussonoubougou has a transitional sub-Sudanian climate with four seasons: a long rainy season (March–June), a short dry season (July–August), a short rainy season (September–October) and a long dry season (November–February) [14]. Mean annual rainfall is 900–1,200 mm [15]; monthly averages for 2000–2010 peaked in June (155 mm) and September (159 mm) (Figure 2a). Mean temperatures are 28–30 °C [16]. The neighbourhood lies on the granitic horst of Bouaké, in an area of pronounced relief [17], with ferrallitic soils over granite [7]. Its southern part is a low-lying area that forms the neighbourhood's natural outlet.

2.2 Household survey

Fieldwork was conducted in several stages. First, direct field observations were made to identify the neighbourhood's stormwater drainage network. Second, a household field survey was conducted using a structured questionnaire. The data collected covered water supply and use, stormwater drainage, solid waste, wastewater and excreta. Household satisfaction and suggested improvements were also recorded. A random sample of 350 households was interviewed. Good-quality data were collected, enabling good-quality results to be obtained.

2.3 Neighbourhood restructuring

The proposed subdivision follows the detailed urban plan (PUd) [7]. The plan was drawn using AutoCAD 2013 and Covadis 2007, then overlaid on the existing built-up area using Global Mapper 20 and Google Earth. The aim was to identify areas requiring reconfiguration and dwellings affected by the new roads and collectors. Where dwellings pre-dated the PUd, road widths were adjusted to limit household displacement.

2.4 Topography and sub-catchments

A GPS survey was carried out across the neighbourhood and used to build a digital terrain model (DTM). Contour lines, sub-catchments and collectors were generated using Covadis (3D contours, roads and drainage module). Ground elevations were extracted automatically from the DTM, and sub-catchments were delineated from streets, roadways and blocks. Collectors were routed to allow gravity flow, thereby preventing water stagnation and limiting earthworks.

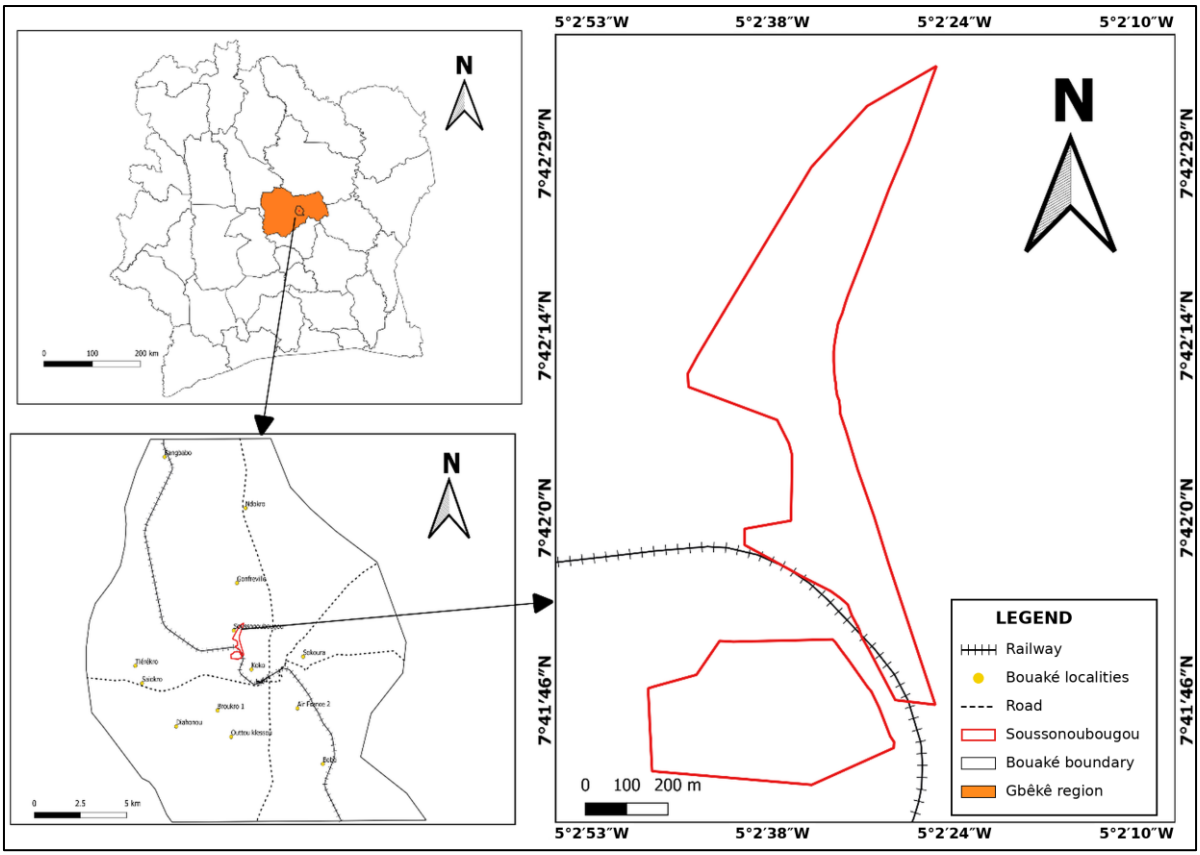

Figure 1: Location of the Soussonoubougou neighbourhood in Bouaké (Côte d'Ivoire).

2.5 Estimation of peak stormwater flows

Rainfall intensity follows the Montana formula, $i = at^b$, where i is intensity (mm/h), t is duration (min), and a and b are the Montana coefficients from the Ivorian technical guidance [18] (Table 1). As Soussonoubougou is urbanised, the Caquot surface method was used. It extends the rational method by accounting for temporary water storage in the network and for the dependence of concentration time on flow and, consequently, on the return period [19,20]. The peak flow Q (m^3/s) of an elementary sub-catchment is:

$$Q = k(T) \times I^u \times C^v \times A^w \times m \quad (1)$$

where I is the mean slope (m/m), C is the runoff coefficient, A is the area (ha), and k, u, v and w are the coefficients listed in Table 1. The correction coefficient m accounts for the elongation M of the sub-catchment when M ≠ 2:

$$m = (M/2)^{0,7b(T)}, \quad M = L/\sqrt{A} \quad (2)$$

where L is the hydraulic length and A is expressed in the same unit of length. The mean slope is I = (Zupstream − Zdownstream)/L [19]. The runoff coefficient was set to 0.9, a value used for very densely built-up areas (0.6–0.7 for dense housing, 0.4–0.5 for less dense housing and 0.2–0.3 for residential areas) [21].

Table 1: Montana coefficients and Caquot parameters used to calculate peak flow.

Return period T (years)	a	b	k	u	v	w
2	397	−0,46	1,45	0,22	1,15	0,83
5	472	−0,46	1,77	0,22	1,15	0,83
10	532	−0,46	2,03	0,22	1,15	0,83

Source: adapted from the DCAD technical guidance [18].

The elementary sub-catchments were then combined in pairs from upstream to downstream, in series or in parallel, to obtain the equivalent parameters and peak flow to be conveyed at each node (Table 2). Whatever the combination, the

equivalent flow must satisfy max (Qj) ≤ Qeq ≤ ΣQj [19]. The return period was set at 5 years for secondary and tertiary collectors and 10 years for primary collectors; the elementary flows presented here correspond to T = 5 years (k = 1.77).

Table 2: Equivalent parameters of sub-catchments combined in series or in parallel (A in ha, L in m).

Parameter	Series	Parallel
Aeq	ΣAj	ΣAj
Ceq	ΣAjCj / ΣAj	ΣAjCj / ΣAj
Leq	ΣLj	L du sous-bassin ayant le Q le plus élevé
Ieq	[ΣLj / Σ(Lj/√Ij)]2	ΣIjQj / ΣQj
Meq	ΣLj / (100√Aeq)	Leq / (100√Aeq)

Source: adapted from [20].

3 RESULTS AND DISCUSSION

3.1 Drinking-water supply

Figure 2 presents the water sources used in Soussonoubougou. A total of 67% of households use well water exclusively, while 29% combine it with rainwater. SODECI water, rainwater, a combination of SODECI water and well water, and a combination of SODECI water, rainwater and well water are each used by 1% of households.

Well water is used for drinking, cooking, personal hygiene, laundry and washing dishes by 80% of households. In addition, 10% of households use well water for drinking, cooking, personal hygiene, laundry, washing dishes and gardening. Only 1% use well water for cooking, toilet use and laundry.

Rainwater is mainly used for cooking, toilet use, laundry and washing dishes (29%). It is also used for laundry and washing dishes by 23% of households. It is used for cooking, toilet use and laundry, and for drinking, cooking, toilet use and laundry, by only 2% for each of these combinations.

SODECI water is mainly used by households for drinking and cooking (67%). A further 17% of households use it for drinking and cooking.

Dissatisfaction with household water supply reaches 97%. A total of 80% of households call for the network to be extended to the neighbourhood. Some 44% request subsidised connections, while 13% request both subsidised connections and network improvements.

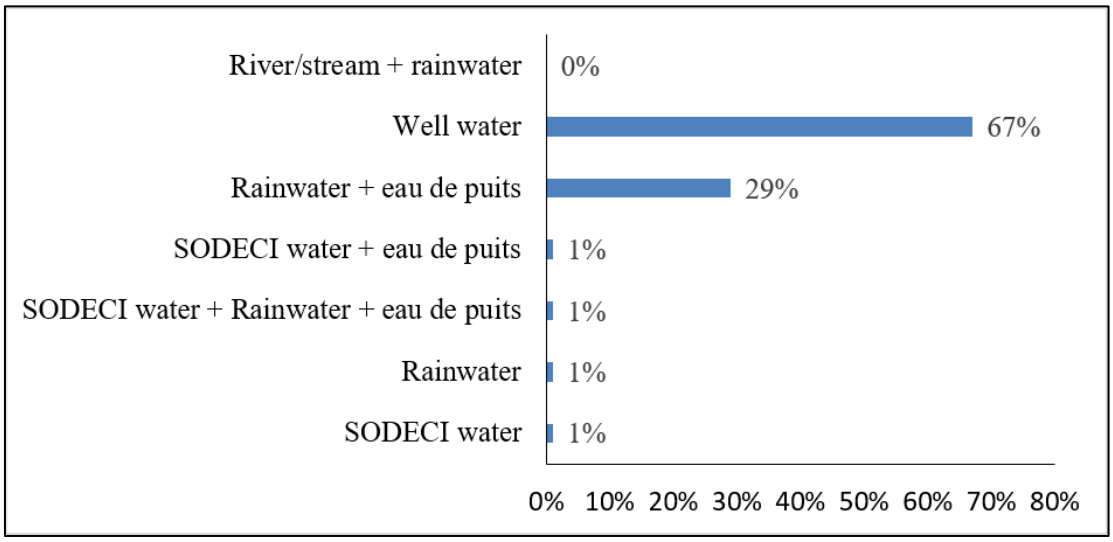

Figure 2: Water sources used in Soussonoubougou

This dependence on wells is a public-health concern, as 12% of sanitation facilities are only 1–2 m from drinking-water wells, while 88% are 3 m or more away. The short distances observed are particularly concerning in light of the

literature. In the neighbourhood, 12% of sanitation facilities are 1–2 m from a drinking-water well and the remaining 88% are at least 3 m away. Recommended separation distances range from 15 to 75 m depending on the country; microbial contamination is generally found within the first 15 m, sometimes up to 25 m, and viruses have been detected as far as 50 m [27]. In sub-Saharan African cities, faecal discharges are a major source of groundwater contamination in densely populated, poorly sanitised neighbourhoods, and traditional wells are among the microbiologically least safe water sources [28]. The effect of distance also varies: in Langas, Kenya, 97% of wells tested positive for faecal coliforms, including 40% located more than 15 m from a latrine, and contamination often increases after rainfall [28]. A distance of 3 m therefore cannot be considered protective. As this study did not include bacteriological analyses, these findings indicate a probable risk rather than a confirmed health impact; sampling a selection of wells should be a monitoring priority.

3.2 Stormwater management

Stormwater is discharged mainly through natural infiltration (65%) or without any intervention (17%); drains are rare (6%), and 9% of arrangements combine drains with infiltration (Figure 3a). Where an outlet exists, it is the street in 92% of cases, a low-lying area in 7% and a drainage network in only 1% (Figure 3b). Overall, 49% of households are dissatisfied with drainage. They attribute the problems to technical causes (34%), a combination of technical causes and uncivil behaviour (27%), uncivil behaviour alone (20%) and the site itself (7%). The main underlying issue is the lack of drainage infrastructure, often combined with unplanned construction (72%). Reported damage includes destroyed roads, damaged belongings, families being unable to move about and flooded homes. Households believe these problems could be addressed through drainage works combined with civic education (54%) or drainage works alone (41%).

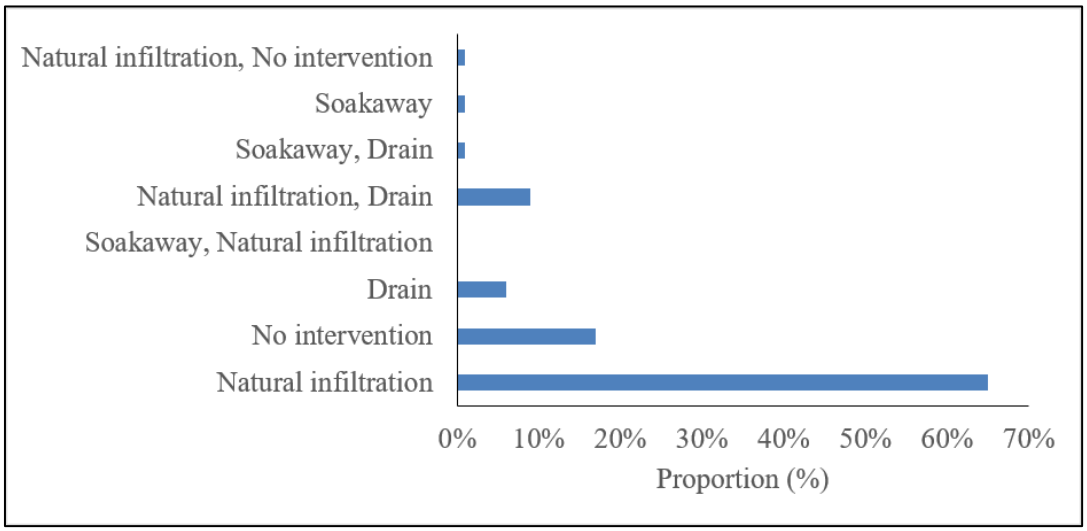

Figure 3: Stormwater management.

The predominance of infiltration (65%) and streets as outlets (92%) indicates the absence of a structured network, a common situation in low-income neighbourhoods where mixing stormwater runoff with wastewater encourages waterborne diseases [30]. This reflects a broader finding: many informal settlements are poorly prepared for flooding because of inadequate drainage infrastructure, and upgrading them in partnership with communities and urban authorities can strengthen resilience to climate change [32]. The proposed gravity-flow layout, which uses an elevation difference of approximately 21 m between the north-west and south, addresses this need while limiting earthworks. Sustainable drainage techniques and green infrastructure could complement the network; however, the literature highlights a lack of data and the low priority given to such measures in sub-Saharan African cities, and recommends first testing them at local community scale [31]. The infiltration capacity of the site's ferrallitic soils over granite must be measured before infiltration is incorporated into the design.

3.3 Solid-waste management

Households mainly store their waste in old buckets (77%) or plastic bags (12%) (Figure 3c). Waste ends up at informal dumpsites (27%), in public bins (24%), at collection points (18%), or at informal dumpsites combined with dumping in the street (15%); approximately half of households (48%) reported dumping their waste indiscriminately, either alone or in combination with other practices (Figure 3d). Respondents attributed this to the absence of public bins (77%) or the distance to them (14%). Dissatisfaction reached 92%. Suggested improvements included additional bins in the neighbourhood (54%), bins closer to homes (30%), a subscription-based pre-collection service (7%), collection points (5%) and the distribution of refuse bags (3%).

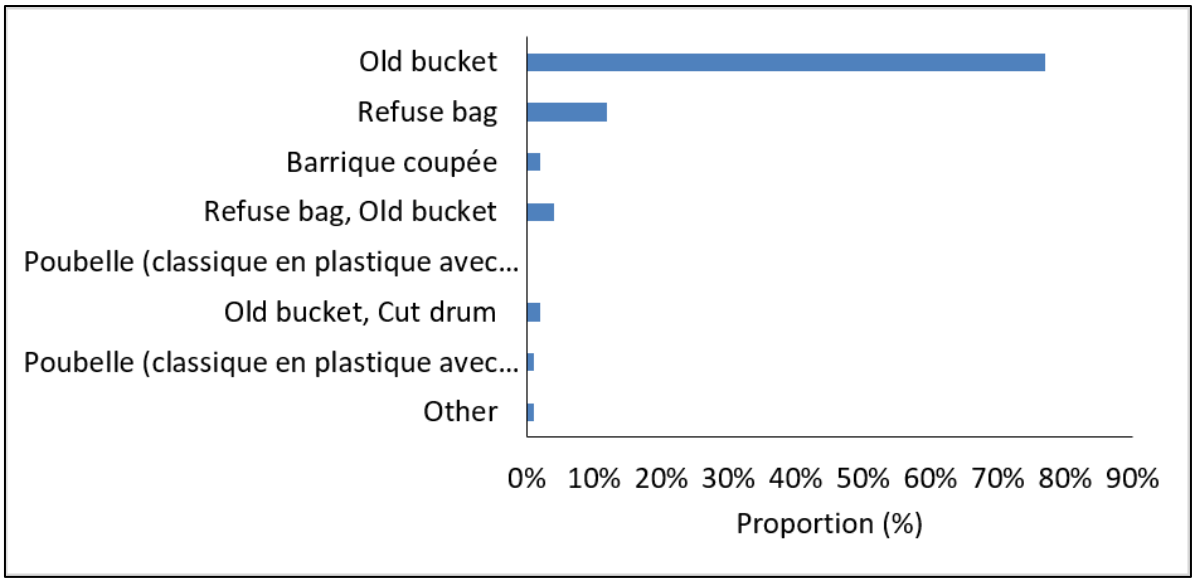

Figure 4: Solid-waste management.

Taken together (Figures 3 and 4), both services are deficient. This diagnosis is consistent with descriptions of informal settlements as places of disorder and hardship [23–25] and supports restructuring that reserves space for basic infrastructure. The unknown destination of sludge, in a neighbourhood where wells supply drinking water, makes the sanitation chain the most urgent complement to drainage.

Waste management is not independent of drainage: solid waste blocks drains and collectors, reduces their capacity and worsens flooding. This supports an integrated approach in which stormwater drainage forms part of sanitation in the broader sense, including household wastewater, excreta and solid waste [30]. The fact that 48% of households report indiscriminate dumping means that the calculated flows will only be conveyed if waste collection and maintenance are ensured; these determine the network's actual capacity. This finding should be considered alongside research on household practices and health risks associated with domestic waste management in Bouaké [13]. For sludge, manual emptying (65%) and lack of knowledge about its final destination (71%) indicate a break in the sanitation chain after containment. Faecal sludge management should instead be conceived as a complete chain, from containment through emptying, transport and treatment to reuse or disposal [36]. In a neighbourhood where wells supply drinking water, this breakdown compounds the risk described in Section 3.1.

3.4 Proposed subdivision plan

The proposed plan (Figure 5) includes 600-m^2 plots, roads 25 m, 15 m and 10 m wide, and plots reserved for public facilities such as green spaces, public areas and health centres. The road widths specified in the PUd (35 m, 30 m and 15 m) had to be reduced to 25 m, 15 m and 10 m because many dwellings pre-dated the plan. The low-lying southern area was not subdivided because it is flood-prone and forms the neighbourhood's natural outlet. Households located outside the blocks and facility plots, on land reserved for roads and collectors, would have to be relocated. The number of affected households was not quantified in this study; a social assessment and compensation are required before implementation.

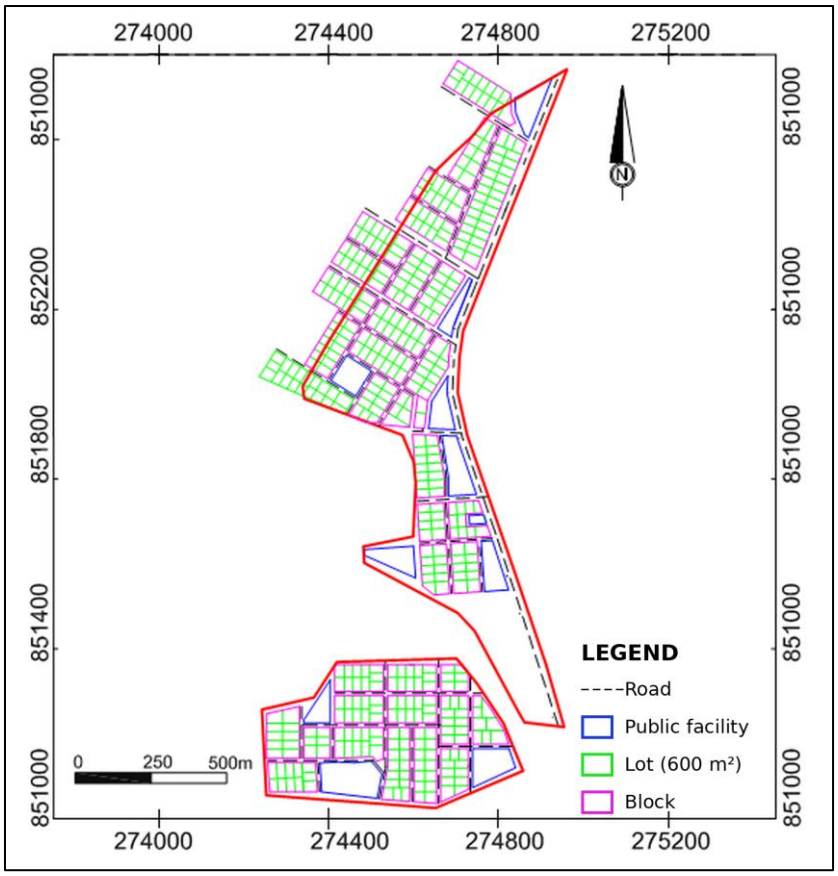

Figure 5: Proposed subdivision plan for Soussonoubougou. Coordinates are in metres (projected coordinate system).

By reducing the rights-of-way in the detailed urban plan (35, 30 and 15 m) to 25, 15 and 10 m to account for existing dwellings, the plan prioritises in-situ restructuring, consistent with the view that upgrading informal settlements strengthens their resilience [32]. This choice has hydraulic and social costs that need to be made explicit. Narrower rights-of-way reduce the space available for collectors, while involuntary displacement exposes households to well-documented risks: loss of land, housing and employment; marginalisation; food insecurity; increased morbidity; loss of access to common resources; and social disruption [33]. The number of households to be relocated, which was not quantified here, must therefore be established before implementation. Conversely, leaving the low-lying southern area unsubdivided applies a principle advocated for drainage in low-income neighbourhoods: uncontrolled construction increases runoff and narrows natural flow paths, while forced evictions exacerbate social problems [30]. The plan therefore preserves the natural outlet while limiting displacement. The integration of the neighbourhood into Bouaké's urban fabric raises broader issues discussed in relation to the city's informal settlements in [11].

3.5 Stormwater flows and drainage layout

Ground elevations range from approximately 367 m in the north-west to 346 m in the south, allowing gravity drainage towards outlets along the lower boundary. The neighbourhood was divided into 84 sub-catchments (total area 44.03 ha; Figure 6), whose characteristics are summarised in Table 3. Slopes range from 0.15% to 5.0%, and elongation M from 0.88 to 2.42. All values fall within, or very close to, the range of validity of the Caquot method [34,35]; only one sub-catchment, with a slope of 0.15%, is flatter than the usual lower limit of 0.2%.

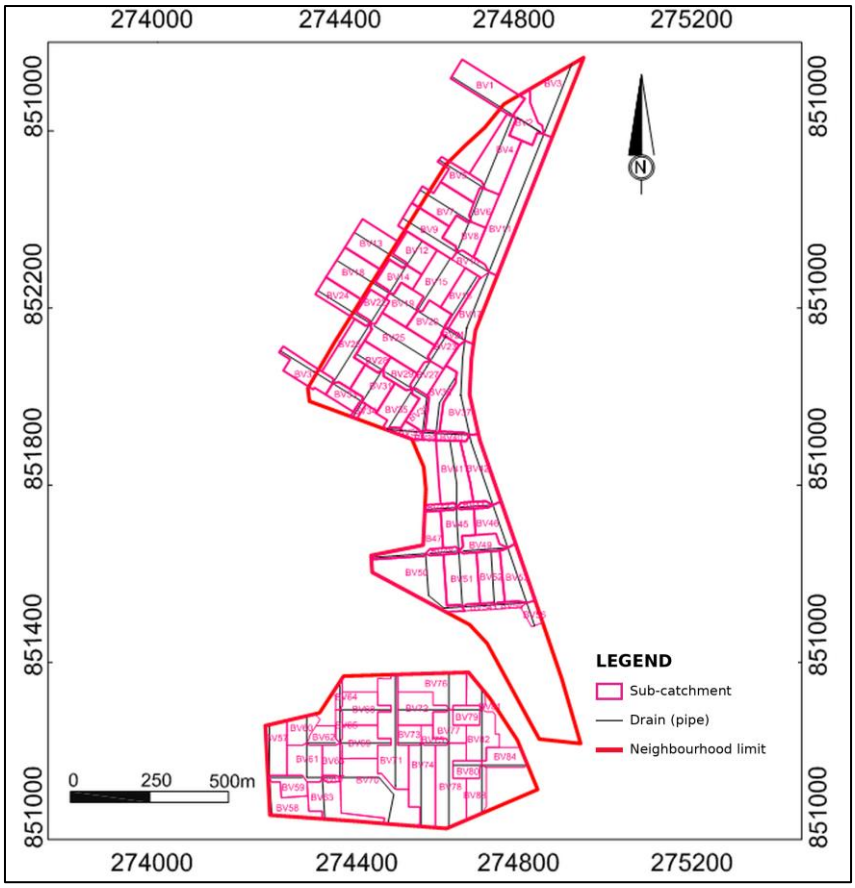

Figure 6: Sub-catchments (BV1–BV84) and collector layout. Coordinates are in metres (projected coordinate system).

Table 3: Characteristics and peak flows (T = 5 years) of the 84 elementary sub-catchments.

Variable	Minimum	Median	Mean	Maximum
Area A (ha)	0,05	0,51	0,52	1,80
Hydraulic length L (m)	29,7	96,6	108,1	335,5
Mean slope I (m/m)	0,0015	0,0154	0,0187	0,0502
Elongation M	0,88	1,54	1,57	2,42
Correction coefficient m	0,94	1,10	1,10	1,32
Peak flow Q (m^3/s)	0,05	0,36	0,41	1,38

Runoff coefficient C = 0.9 for all sub-catchments. Sum of elementary flows: 34.1 m^3/s.

Elementary peak flows range from 0.05 to 1.38 m^3/s and increase with area (Pearson's r = 0.92; Figure 7a). The combination process produced 75 equivalent nodes and seven outlets draining 38.7 ha (Table 4). The highest flow, approximately 8.2 m^3/s, is conveyed by the northern collector, which drains 25.7 ha. Its specific discharge (0.32 $m^3\ s^{-1}\ ha^{-1}$) is less than half the mean elementary value (0.77 $m^3\ s^{-1}\ ha^{-1}$), owing to the storage and concentration-time effects incorporated into the method (Figure 7b).

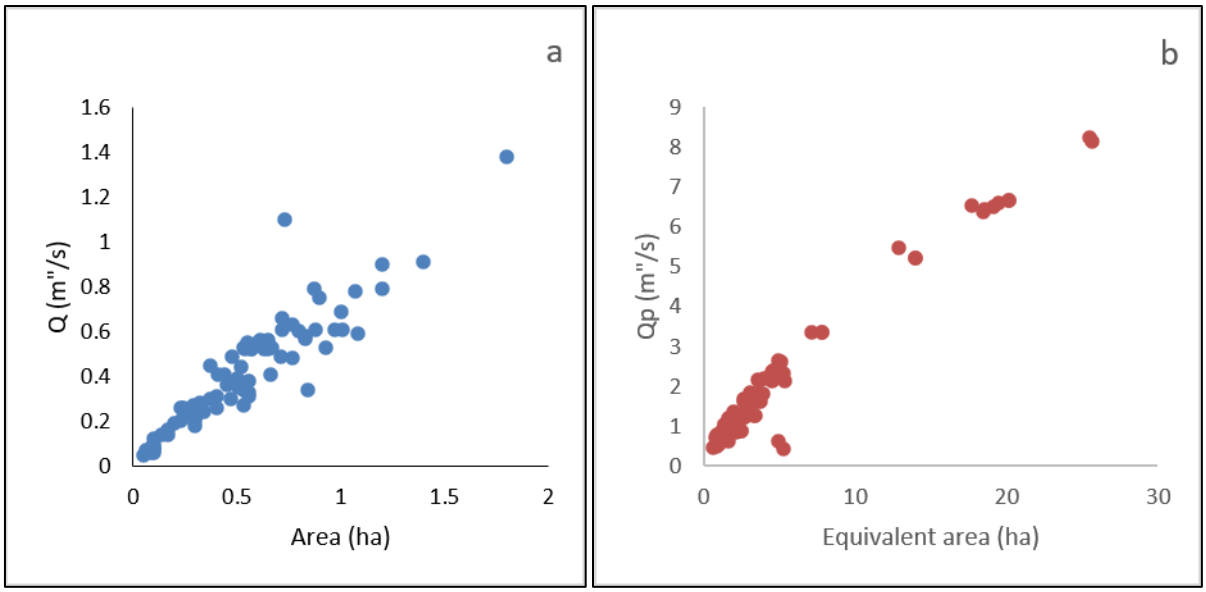

Figure 7: Peak flows for T = 5 years. (a) Elementary sub-catchments. (b) Equivalent nodes obtained by combining sub-catchments in series and in parallel.

Eq47: the spreadsheet gives 8.13 m^3/s, whereas the upstream node Eq46 gives 8.23 m^3/s. Since Qeq ≥ max(Qj), the higher value should be retained for design. Ceq = 0.9 at all nodes.

Table 4: Equivalent parameters and peak flows at the seven outlets of the drainage network.

Outlet (node)	Area (ha)	Leq (m)	Ieq (m/m)	Meq	Qeq (m^3/s)
Eq47 (north)	25,68	1418	0,014	2,80	8,13
Eq58	4,06	342	0,017	1,70	2,16
Eq53	2,00	268	0,035	1,90	1,36
Eq75	3,41	420	0,005	2,27	1,28
Eq68	1,48	228	0,030	1,88	1,03
Eq49	1,39	204	0,038	1,73	1,06
Eq66	0,65	174	0,017	2,16	0,44

The neighbourhood's characteristics fall within the usual application range of the surface method: urban catchments smaller than 200 ha, slopes of 0.2–5%, and no storage structures [35,36]. Here, the whole area covers 44 ha, the sub-catchments do not exceed 1.8 ha, and their slopes range from 0.15% to 5.0%, with only one sub-catchment flatter than the usual lower limit. Although originally presented as a variant of the rational method, the method provides only the peak flow at the outlet; it is no longer sufficient when storage structures or hydrograph analysis are considered, and Desbordes' tests showed that the parameters in the 1949 guidance substantially underestimated flows [34]. The 8.2 m^3/s estimated for the northern collector should therefore be treated as a design basis for a network without storage, and checked against a more detailed hydrological model if detention basins are planned. Furthermore, runoff formulae developed in industrialised countries do not transfer well to humid tropical regions [30]; calibration against local rainfall and flow measurements would strengthen the Montana coefficients dating from 1979 [18], particularly as climate variability has been documented in Côte d'Ivoire [15].

The reduction in specific discharge, from 0.77 $m^3\ s^{-1}\ ha^{-1}$ at the elementary scale to 0.32 $m^3\ s^{-1}\ ha^{-1}$ in the northern collector, arises first from the formula itself: the area exponent (w = 0.83 < 1) means that Q/A varies as $A^{(-0.17)}$. Between an average sub-catchment (0.52 ha) and the northern collector catchment (25.7 ha), an area ratio of approximately 49, this exponent alone would reduce specific discharge to about half ($49^{(-0.17)} \approx 0.52$). Elongation and the equivalent parameters for series and parallel combinations (Table 2) complete the effect, resulting in an observed factor of 0.32/0.77 ≈ 0.42. This attenuation justifies sizing each collector using the flow at its equivalent node rather than the sum of elementary flows (34.1 m^3/s for all sub-catchments).

3.6 Implications and limitations

Three points should guide the use of these flows. First, T = 5 years is appropriate for secondary and tertiary collectors, but primary collectors designed for T = 10 years require recalculation; at the elementary scale, decennial flows are approximately 15% higher (ratio of k values: 2.03/1.77). Second, the uniform coefficient C = 0.9 is conservative for the restructured neighbourhood, where 600-m^2 plots and public spaces imply a lower density; with C = 0.6–0.7, flows would be approximately 25–37% lower because Q varies as C^1.15. Third, the Montana coefficients date from 1979 and may not reflect recent rainfall variability or climate change [20]. The study is also limited to one neighbourhood, relies on self-reported data, and does not yet include pipe sizing or costs.

As drainage alone will not resolve the problems identified, the plan should be accompanied by a solid-waste management system (bins and collection points), shared toilets managed by a management committee, improved drinking-water supply and improved village water-supply infrastructure (HVA) where immediate network expansion is not feasible, with a formal commitment from the State.

The recommendation for shared toilets managed by a committee needs qualification. A systematic review found a higher risk of diarrhoea with shared latrines than with individual household latrines (pooled odds ratio 1.44; 95% CI: 1.18–1.76), while also highlighting the weakness of the evidence: observational studies, substantial heterogeneity and infrequent reporting of the number of households sharing facilities [29]. The number of households per block, maintenance and access therefore determine whether this option is appropriate; it must be designed and monitored as a shared facility and not presented as equivalent to individual latrines.

Taken as a whole, the approach links three stages that are usually addressed separately: a household-level sanitation assessment, a subdivision plan constrained by both existing buildings and topography, and a peak-flow calculation based on sub-catchments delineated from the layout itself. The plan defines the areas and slopes assessed by the hydrological analysis; the resulting flows, in turn, indicate the rights-of-way that must be reserved for collectors. This sequence responds to calls for an integrated approach in which drainage is considered alongside waste, wastewater and urban planning [30], and relies on accessible data and tools in a context where measurements are scarce. Its limitations arise from the method (peak flow only, no storage), a conservative runoff coefficient, outdated rainfall coefficients and a diagnosis based on self-reported information.

4 CONCLUSION

This study combined a household sanitation survey, a subdivision plan and an estimate of peak flows for the informal settlement of Soussonoubougou in Bouaké. The survey showed that households depend on wells, stormwater and greywater are discharged without a network, solid waste collection is inadequate, and the final destination of pit sludge is largely unknown. The proposed plan, with 600-m^2 plots, roads 10–25 m wide and plots reserved for public facilities, adapts the detailed urban plan to existing dwellings and keeps the low-lying southern area free of construction. The 84 sub-catchments (44 ha) generate elementary peak flows of 0.05–1.38 m^3/s (T = 5 years), and the main northern collector must convey approximately 8.2 m^3/s. Future work should size the collectors, recalculate primary collectors for T = 10 years using a runoff coefficient suited to the new layout, quantify the number of households to be relocated, and estimate the cost of integrated measures for water supply, waste and sanitation.

STATEMENTS ON COMPLIANCE WITH ETHICAL STANDARDS

Acknowledgments

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Disclosure of conflict of interest

The authors declare that they have no conflicts of interest.

Statement of informed consent

Participation in the household survey was voluntary and informed consent was obtained orally from all respondents; responses were anonymised. The study involved neither clinical data nor experiments on humans or animals.

REFERENCES

[1] Chaboche M, Preuvot N, Dukhan A. The AFD and intervention in deprived neighbourhoods: lessons learnt and strategic recommendations. Paris: Agence Française de Développement; 4 April 2014. 48 pp.

[2] Véron J. Half the world's population lives in cities. Population et Sociétés. June 2007;(435).

[3] Baechler L. Access to water: a key issue for sustainable development. 2017. Available at: https://www.decitre.fr/media/pdf/feuilletage/9/7/8/2/8/0/7/3/9782807302280.pdf

[4] United Nations. The Millennium Development Goals Report 2013 (French edition). New York: United Nations; 2013. Available at: http://mdgs.un.org/unsd/mdg/Resources/Static/Products/Progress2013/French2013.pdf

[5] National Institute of Statistics. General Population and Housing Census (RGPH) 2014: implementation report and presentation of key findings. Abidjan: INS; 2014. 49 pp.

[6] Ministry of Construction, Housing, Sanitation and Urban Planning (MCLAU), Directorate of Urban Planning. Bouaké 2030 Master Plan (SDU), phase 1: strategic assessment. Abidjan: URBAPLAN-TRANSITEC-IAO; 2014

[7] Ministry of Economic Infrastructure (MIE). Infrastructure Project for Urban Development and the Competitiveness of Secondary Urban Areas (PIDUCAS): Environmental and Social Impact Assessment (CIES) of the sub-projects for the development of the Bouaké city crossing and the rest area on the northern corridor. Abidjan: MIE; 2017. 178 pp.

[8] Assue YJ, Traoré F. Issues relating to informal settlements in the city of Bouaké: causes and consequences for the development of the urban fabric. 2019. 19 pp.

[9] Saïdouni M. An Introduction to Urban Planning: History, Methodology, Regulation. Algiers: Casbah; 2000. 136 pp.

[10] Merlin P, Choay F, eds. Dictionary of Urban Planning and Development. Paris: Presses Universitaires de France; 1988. 723 pp.

[11] Doho BT, Assue YJ, Kouakou B, Koffi B. Approaches to the integration of informal settlements in the city of Bouaké. Regards Suds. 2019. Available at: https://regardsuds.org/les_logiques_d_integration_des_quartiers_d_habitat_precaires_dans_la_ville_de_bouake

[12] Yeo B. Decentralisation and local development in the municipality of Bouaké [doctoral thesis]. Bouaké: Alassane Ouattara University; 2019. 422 pp.

[13] Kouakou K. Household perceptions, practices and health risks associated with household waste management in urban areas in Côte d'Ivoire: the case of the cities of Bouaké and Tiassalé [doctoral thesis]. Bouaké: Alassane Ouattara University; 2017. 513 pp.

[14] N'Guessan KF, Koli B, N'Zi K. Some factors explaining changes in vegetation cover in the Gbêkê region (Côte d'Ivoire). Int J Inf Res Rev. 2016;36:1661–5.

[15] Brou YT, Akindès F, Bigot S. Climate variability in Côte d'Ivoire: between social perceptions and agricultural responses. Cah Agric. 2005;14(6):533–40.

[16] Municipal Operations Support Mission (MACOM). Urban Infrastructure Emergency Project (PUIUR). 2008. 89 pp.

[17] Soro N, Koné AA. Topographical characteristics and distribution of housing in the city of Bouaké. 2019. Available at: https://www.revuegeo-univdaloa.net/fr/publication/caracteristiques-du-relief-et-repartition-de-lhabitat-dans-la-ville-debouake

[18] Central Directorate for Sanitation and Drainage (DCAD). Study of the intensity of exceptional downpours. Technical guidelines on sewerage networks. 1979. 53 pp.

[19] Satin M, Selmi B (edited by Bourrier R). Technical guide to sanitation. Paris: Le Moniteur. [edition, year and page count to be confirmed: the bibliographic record consulted states 1st ed. 1999, 660 pp.; the manuscript states 2010, 776 pp.]

[20] Yao T. Contribution to sustainable stormwater management in the context of climate change: the case of the city of Korhogo [Master's thesis]. Ouagadougou: International Institute for Water and Environmental Engineering (2iE); 2009. 53 pp.

[21] Chibane F. Study of sanitation and drinking water supply in an expansion area in Tagna, municipality of Ain Fezza [Master's thesis]. Tlemcen: University of Tlemcen; 2011. 76 pp.

[22] Sy I, Diagana I, Reymond V, Ulrich L, Bourqui P. Survey of sanitation systems in the informal settlements of Nezaha (El Mina) and Tarhil (Riyadh), Nouakchott: study report, final version. Nouakchott Urban Community, Eawag-Sandec; January 2013.

[23] Yapi D. Territories and profiles of urban precariousness in Abidjan. In: Hexapolis Conferences: six megacities facing the challenge of new inequalities. Paris; 2000. 17 pp.

[24] Yapi D. Urban research put to the test by marginalised communities in the city. Abidjan: EDUCI; 2003. 123 pp.

[25] Assue Y. Areas of poverty in the city of Bouaké. Germivoire (special issue). 2017:63–77.

[26] Julien W. Regeneration of Lure town centre [engineering final-year project]. Strasbourg: INSA Strasbourg; 2009.

[27] Graham JP, Polizzotto ML. Pit latrines and their impacts on groundwater quality: a systematic review. Environ Health Perspect. 2013;121(5):521–30.

[28] Lapworth DJ, Nkhuwa DCW, Okotto-Okotto J, Pedley S, Stuart ME, Tijani MN, et al. Urban groundwater quality in sub-Saharan Africa: current status and implications for water security and public health. Hydrogeol J. 2017;25(4):1093–116. doi:10.1007/s10040-016-1516-6

[29] Heijnen M, Cumming O, Peletz R, Chan GK-S, Brown J, Baker K, et al. Shared sanitation versus individual household latrines: a systematic review of health outcomes. PLoS ONE. 2014;9(4):e93300.

[30] Parkinson J. Urban drainage in developing countries – challenges and opportunities. Waterlines. 2002;20(4):2–5.

[31] Mguni P, Herslund L, Jensen MB. Sustainable urban drainage systems: examining the potential for green infrastructure-based stormwater management for cities in Sub-Saharan Africa. Nat Hazards. 2016;82(2):241–57. doi:10.1007/s11069-016-2309-x

[32] Satterthwaite D, Archer D, Colenbrander S, Dodman D, Hardoy J, Mitlin D, et al. Building resilience to climate change in informal settlements. One Earth. 2020;2(2):143–54. doi:10.1016/j.oneear.2020.02.002 [page numbers to be confirmed]

[33] Cernea MM. The risks and reconstruction model for resettling displaced populations. World Dev. 1997;25(10):1569–87.

[34] Desbordes M. A general study of urban stormwater drainage. La Houille Blanche. 1975;(1):37–43.

[35] Interministerial Circular No. 77-284 of 22 June 1977 concerning technical guidelines for urban drainage networks. Paris: Imprimerie Nationale; 1977.

[36] Strande L, Ronteltap M, Brdjanovic D, editors. Faecal sludge management: a systems approach for implementation and operation. London: IWA Publishing; 2014.

[37] United Nations. The Millennium Development Goals Report 2012. New York: United Nations; 2012.