Developing a Sewerage Management System for Kisii Town Using GIS and Remote Sensing

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Abstract—Rapid population growth, coupled with failing and outdated sewer infrastructure, is overstretching sewer systems in Kenya leading to sewerage pollution. The usual manual based, localized, “find and fix as you go” approach is neither reliable nor cost effective and cannot be relied on to improve system design and its overall performance. This study was undertaken to develop a sewerage management system for Kisii town in Kisii County using Geospatial technologies and propose a new sewer line. To achieve these objectives, primary and secondary datasets including Kisii Town development plans, High resolution satellite images, topographical maps, population data, questionnaires based interviews and GPS mapping were used in GIS environment to analyze and model the sewer system. The Analytical Hierarchical Process (AHP) which relies on the judgment of experts in assigning weights was used in optimizing the location of the proposed new sewer line. Results show that seventy percent of the available data is not accessible, that accessing the data is very slow and expensive and substantial numbers of files are either missing or misplaced. Questionnaire analysis results indicate that majority of those interviewed would prefer the computerization of the sewage information system for Kisii Town. Model results show that the optimal areas lie near Daraja mbili area as the base for the proposed sewer line. The research findings indicate that the County government of Kisii could benefit through the use of geospatial technologies to facilitate the management of data and implementation of sewer models.

Keywords—Geospatial technologies, Kisii, modeling sewer line, sewerage management system

I. INTRODUCTION

A ccording to Kenya’s development blueprint, the Vision 2030, the country aims to have clean, secure and sustainable environment by ensuring improved waste management through the design and application of economic incentives for improved efficiency in water and sanitation delivery. This will also ensure reduced environmental related diseases by ensuring improved water and sanitation in both urban and rural areas. It is estimated that by the year 2030, most of Kenya’s population will be urban and therefore there is need to provide for secure plans for decent and high quality urban livelihood (Kenya Vision 2030).

Kenya’s vision 2030 pillar on infrastructure envisages a country that will be firmly interconnected through a network of water and sanitation systems. Access to safe drinking water, basic sanitation and proper hygiene can prevent waterborne diseases by nearly 90% and lead to improved health, poverty reduction and socio-economic development. The Millennium Development goals (MDG) set by the United Nations requires developing countries to reduce by halve the proportion of people without sustainable access to safe drinking water and basic sanitation by the year 2015. Anthropogenic activities have unbearably contaminated and polluted surface water resources. Groundwater is also becoming polluted with increasing frequency, and the resulting dangers to man are alarming because polluted water is a very sure pathway of numerous infectious disease causing organisms, (Tumunobereon-ari. et al., 2013)

The task of designing a new sewer line is an important task thus proper planning is essential in order to maximize the benefits derivable from the use of the sewer line (Balogun et al. 2012). With the careful planning of a route, cost, time, and operating expenses can be saved, ensuring longer operational life and minimizing environmental pollution.

The major objective of this research is creating a sewer database, GIS analysis and spatial modeling in order to come up with an optimal sewer line system for Kisii County. GIS tools which bring new approaches to sewer line routing enabling all factors affecting the route be considered and weighted under one umbrella. GIS includes scientific and technological tools that enable the integration of data from different sources into a centralized database from which the data is modeled and analyzed based on its spatial component. The inefficient and traditional methods of optimal sewer line location are mainly based on expensive and protracted methods. These methods utilize static paper maps which are huge and bulky, furthermore, they are not precise and the role of all effective parameters in sewer line location cannot be easily considered. Technical, economic and environmental concerns are not observed in designed paths as a result of these outdated methods. This calls for a method that overhauls all the demerits. GIS methods are efficient tools for decision making which are effective and efficient. GIS-based tools and processes have been extensively used to address the challenges of optimizing sewer line networks based on the collection, processing and analysis of spatial data. GIS-based tools and processes have been extensively used to address the challenges of optimizing sewer lines, selection and route networks based on the collection, processing and analysis of spatial data such as topography, vegetation, soil type, land use, geology and landslide areas. It represents an approach to sewer line location that is systematic and effective. Optimizing a sewer line is essentially an optimization between costs of the material and the costs of the construction, spatial variations in construction cost due to changing features like types of soils, intervals of slope. GIS allows the engineer to use dynamic spatial models to aid in selecting an optimized sewer line location. The GIS software and data enables the processing of a large amount of location-based information to find optimal locations by taking into account natural and manmade obstructions.

The problems facing the area have been compounded by gaps in research and limited emphasis on the assessment of change through spatial information technologies such as GIS. Using remotely sensed satellite imagery and GIS modeling, an Urban spatial data infrastructures and spatial analysis are growing hence GIS approach is very efficient as a tool to facilitate the decision-making process. To allow urban management modernization and future distribution of...
activities in space, there are needs to have a tool or support system, which will handle the larger volume of spatial and non-spatial. This system will be capable of carrying out complex and sophisticated analysis, processes and eventually produce sustainable and efficient plans (Muthusamy, 2003)

**Problem statement**

Kisii County development profile 2013, indicate that the county headquarters has had a rapid increase in population. It is home to major businesses, institutions of higher learning and commercial banks. Kisii town however, does not have appropriate drainage systems. The existing one is old and dilapidated. Waste is not properly managed since most households are not connected to the existing sewer lines. Waste disposal in many places is by landfills through Pit latrines which is unhygienic and a health hazard. This has resulted in poor sanitation and environmental pollution which have led to outbreak of water borne diseases.

With its new status as a county headquarters, Kisii town urgently needs better services to serve the expected increase in population.

**Objectives of the study**

The major objective of the study is to develop sewerage Management System for the Kisii town that will allow proposing a new sewer line for Kisii Town. This will involve Geo database creation, spatial modeling and GIS analysis for optimal sewer line location. This will also involve deriving a weighting criterion for sewer line planning using Analytical Hierarchy Process and modeling using these weightages, in the process of sewer line location.

To carry out a detailed analysis of the existing sewer system;

To create a GIS database for sewerage management and information system for Kisii town and to propose a new sewer line to serve Kisii Town.

**Research questions**

What is the current status of sewer services in Kisii Town?

What’s the best method that can be used to weight the different variables that affect the sewer line? And What would be the optimal sewer line location for Kisii Town?

Absence of a functional sewer line location will lead to poor sanitation and environmental pollution which will be detrimental to the Kenyan economy. The traditional methods of sewer line location are inefficient and do not consider all the possible variables. Due to the hilly topography, the frequent rains and ineffective drainage system, management of water sewerage services have remained a challenge.

Kenya government has put in a lot effort ensure the country improves sanitation standards and eradicates water borne diseases while at the same time ensuring that devolved governments are functional. The government also desires to meet the Millennium development goals, As per the Final project report of September 2008, Gusii Water and Sanitation Company (GWASCO) was Selected in the Lake Victoria to achieve Millennium Development Goal(MDG) targets for water and sanitation in small urban centers, taking into account the physical planning needs of these urban centers together with attention to drainage and solid waste management as an integral part of environmental sanitation, as well as requirements of other multilateral agreement. This research work is therefore in line with the government’s agenda in the health sector.

Implementing a sewer system using GIS has advantages in terms of speed of data processing and analytical capability. Manual sewer location processes are very tedious in nature (Henley & Henning Dresp, 2012). Currently sewerage information in Kisii is held mostly in paper form and managed manually. Once implemented, GIS can be used to analyze different location scenarios and allow quick decision making for resource management.

Achieving vision 2030 targets will be difficult if not impossible without clean living environment and proper sanitation. The construction of the sewer line in Kisii will contribute to attainment of vision 2030 by ensuring proper management of sewerage. After the promulgation of the new constitution of Kenya, 2010 (COK 2010), water and sanitation were among the services that were devolved from the national Government to the counties. The New constitution emphasizes access to clean and safe water in adequate quantities and reasonable standards of sanitation. This project is therefore in support of the implementation of devolved governments as required under the new constitution. The most significant deficiencies in the sewer line projects carried out in Kenya and elsewhere include among others lack of clear decision-making criteria and methods alongside inadequate stakeholder involvement (Taylor et al. 2007). This will be addressed in the method devised for weighting and involvement of some of the stake holders such that there will be improvement in decision consensus. Due to unavailability of data, this study is limited to the municipality of Kisii and not the entire Kisii County as originally envisaged.

**BACKGROUND**

The GIS approach to sewer management and sewer line routing optimization is based on relative rankings and weights assigned to project specific factors that may affect the potential location. The result of this process is an optimal path which maps out that most economic location (Henley & Dresp, 2012). Planning for the sewer optimum route will require an extensive evaluation process to identify the best possible path. The factors are chosen to balance engineering and construction costs against environmental costs and its sustainability.

Manual sewer line planning uses available maps, surveys and experience but may be heavily constrained due to lack of updated data and quantitative approach. This is accentuated for complex terrains and lengthy routes. GIS method on the contrary uses updated maps from latest Remote Sensing data, integrates thematic cost layers in GIS environment and computes all possible routes with associated costs making it the most reliable (Dubey, 2000). During the last decade, a few attempts have been made to automate sewer route planning process using GIS technology and the methodology is still at an exploratory stage. Moreover, due to the complexity of the routing problem, the proposed methods have not been tested in very high altitude rugged terrains (Saha et al. 2005). In a study done by (Saha et al. 2005) concludes that computer assisted methodology of route planning is very fast in comparison with the conventional manual practice. It takes 13 minutes for a test area of 1.5km by 1.5 km using the computer-based, least-cost, and route-finding process in contrast; the same process may take many days by the manual approach, even if all the datasets are readily available. He proposes an algorithm which its efficiency can further be increased as the processing technology advances.

He further observes that with GIS-based methodology, it is possible to integrate and analyze various parameters related to sewer route development and maintenance at the same time. In the manual method, it is difficult to consider a large number of parameters at the same time to conduct a purposeful analysis. In manual sewer route-alignment practice, it is quite possible that an alternate best route becomes unknowingly overlooked. In contrast, the methodology he proposes an algorithm to find the least-cost path. The algorithm is intelligent, fast and efficient, and considers all possible combinations of routes between the source and the destination points. Therefore, the least cost path identified by the algorithm would provide the best option with certainty.
The weighting-rating values he used were based on a comparative study of various thematic data layers and discussions with different experts working in different areas of specializations. The weighting values used is the raw comparisons from the expert; a sewer line that avoids landslide prone areas saves on time as opposed to the manual process was the result of the study. A study done in the Caspian Sea region utilizes remote sensing and GIS tools to come up with costs associated with terrain conditions, land use among others. The costs were computed based on the experience of various earlier sewer projects. The Spatial Analyst module was used to extract the least-cost route from a cumulative cost surface. It was shown that the least-cost path derived in this study was 21% (52km against 42km) longer than the straight-line path between the source and destination, but it led to a reduction in construction costs of 14% in the area considered (Feldman et al. 1995).

The model developed incorporated pipeline length, topography, geology, land use, and stream, wetland, road, and railroad crossings. Satellite remote sensing imagery was used as a base to display results and the land cover. The length and cost associated with a straight line path between four predetermined points along a section of the sewer line were compared with the length and cost of the least cost pathway. The least cost pathway avoided urban and industrial cells on the straight line route. The weighting criteria used is not documented.

A similar research was carried out to come up with an optimal route location in Malaysia using GIS and specifically the spatial analyst module of Arc/Info in ArcGIS. The integration of GIS and Multi-criteria decision Analysis (MCDA) in optimal route selection was analyzed. To further validate the findings, he involved the community in weight derivation although no comparison was done using an existing route in order to validate the results. The two methods provide insights on how they can complement each other in ensuring a very high level of accuracy in the generated route (Balogun et al. 2012).

In an AHP based study to investigate MCDA weighting GIS methodology and Analytical Hierarchy Process were combined to derive weightages for routing. The mode of gathering expert opinion for the AHP model could not be implemented in its conventional form, because it could not incorporate the sub classes of particular criteria. An attempt to do so would have been inconsistent and tedious in making the pair wise comparison. The AHP model was modified and the results showed that it scores over the conventional method of gathering pair wise comparisons (Suresh & Nonis, 2007).

Epidemics or disease outbreak can result when sanitation is not given considerable attention, (Burian et.al, 2000).Several researches have also documented the consequences of poor sewerage management. Lack of proper sewage systems can result in the contamination of surface water and groundwater, and the subsequent spread of infectious diseases associated with sewage such as cholera, and typhoid fever, (Tamuonoberet-onari et.al, 2013)

At the very first level, locations are reflected as a unified geo-referencing framework which can be used to integrate geospatial data and maps. General public without professional knowledge can easily compare and investigate various planning scenarios. Since urban planning is normally based on the status quo evaluation of the complex urban system and simulation of possible solutions, it may not be practical to consider all factors in one model, (Tao, 2013). There are two main steps in implementing a solid waste management program. These steps include the identification of potential sites through preliminary screening, and the evaluation of their suitability based on environmental impact assessment, engineering design and cost comparison preliminary screening which should be pragmatic so that areas of social and environmental significance are excluded without removing large numbers of technically advantageous sites from consideration. This issue of optimum criteria and appropriate methodologies is vital in most developing countries because planning regulations are not as well established like areas with steep slopes, in a decision-making process, the human cognitive evaluative structure is rather inexact. Analytic hierarchy process (AHP) is used to derive weights for criteria’s maps (Champratheep et al., 1997). Use of multicriteria evaluation by incorporating the AHP method (Saaty 1980) is based on a composite suitability analysis using map overlays, (O’Leary et al. 1986).

There is need to implement policies and measures in such a way as to minimize adverse effects on environmental impacts: Solid waste disposal on land and Wastewater handling, (Kyoto protocol,1998), hence there is need to locate meters to maximize the likelihood of detecting system blockages and sanitary sewer overflows (SSO) disruptions. The problem is solved using a set-covering approach and allows the trade-off between the number of detections and the cost of gauges to be easily assessed, (Sier and Lansey, 2005).

A study by Gruen (2013) reveals that “smartness” can be expressed by its 6-axes model: smart economy, mobility, environment, people, living and governance. Only if all these elements are in balance a city can fulfil its request for sustainability and quality of life. A smart city possesses spatial intelligence. This summarizes all components in terms of brain, hard and software, which are required to manage a city efficiently with the goal to sustain high quality of life over a long period of time (resilience). As such, it refers to informational and cognitive processes, such as information collection and processing, real-time alert, forecasting, learning, collective intelligence and distributed problem solving. In this environment, the Geo-Spatial Information Sciences play a key role, providing for the underlying theoretical framework and practical procedures for data acquisition, processing, analysis and representation.

Gerhager and Sahooly (2009) asserts that the technical interventions in Yemen In the early 1990s were implemented through future investment planning and the set-up of a geographic information system, while training programmes for technical tasks supporting the improvement of the investment and services.

The waste management hierarchy can be ranked according to the preferences given to prevention from waste followed by waste reduction, re-use, recycling and energy recovery. Principles of the use and disposal of waste, waste management plans, approval procedures, and monitoring, are also to be explored, (Przewrocki et al., 2004).

Analytic Hierarchy Process (AHP) is a multi-criteria decision-making approach and was introduced by Saaty. The AHP has attracted the interest of many researchers mainly due to the nice mathematical properties of the method and the fact that the required input data are rather easy to obtain. In many industrial engineering applications the final decision is based on the evaluation of a number of alternatives in terms of a number of criteria. This problem may become very difficult one when the criteria are expressed in different units or the pertinent data are difficult to be quantified. The Analytic Hierarchy Process (AHP) is therefore an effective approach in dealing with this kind of decision problems.

AHP is an analytical tool that enables explicit ranking of tangible and intangible criteria against each other for the purpose of selecting priorities, (Saaty, 1994). The process involves structuring a problem from a primary objective to secondary levels of criteria and alternatives. Once the hierarchy has been established, a pair wise comparison matrix of each element within each level is constructed. AHP allows group decision-making, where group members can use their expertise, experience, and knowledge to break down a problem into a hierarchy and solve it by the AHP steps. Comparisons are made based on standards established by experience (saaty,1990). The smaller of each pair is used as the unit and the larger one is measured in terms of multiples of the unit.
Very often qualitative data cannot be known in terms of absolute values. Pair wise comparison has been used to determine the importance of a given computer software in terms of user adaptability criteria this calls for relative qualification or weighting. A study by Charmpatheep et al. (1997) applied GIS and the analytic hierarchy process (AHP) for preliminary land fill site screening the identification of potential sites through preliminary screening, and the evaluation of their suitability based on environmental impact assessment, engineering design and cost comparison , unsuitable areas were excluded and retained potential areas for the evaluation process. The criteria used for preliminary screening include primarily the proximity of potential sites to geographic objects that may be affected by the landfill like groundwater wells or that may affect landfill operations like areas with steep slopes. Methodologies used were based on a composite suitability analysis using map overlays. Based on selected criteria, by creating buffer zones around geographic features to be protected. All map layers were then interseetected so that the resulting composite map contains two distinct areas For example, when saying the preliminary landfill site should be far away from a built-up area, the question of how far is far arises. One may arbitrarily set the boundary between far and not far. Criteria used for the preliminary site screening are distance from key geographic features and topography. These are organized into four main groups: human settlement, natural resources, roads and topography. The human settlement group includes the distance from groundwater wells, schools, villages, temples, urban built-up areas and archaeological sites.

GIS and MCDA techniques have been widely applied for Railway Route Selection for the Proposed Kenya-Sudan Railway, (Kiema et al.2014). Based on GIS and Multi-Criteria analysis, railway design needs are assessed and suitable factors and constraints for analysis are derived. Various map layers were prepared and reclassified to meet the various needs. Layers are combined with the destination to automatically generate four alternative routes each constrained to pass through a priori selected locations along the corridor from which the most optimal one was selected.

In the study, GIS-based simulation of urban sewerage flow volume by Yoo, 2005. Sewerge flow Volume simulations for all pipelines allowed the calculation of preferable pipe sizes for calculated volumes under assumed conditions and thus the identification of pipes most prone to cause flooding if sewerage flow volumes increase due to redevelopment population increase. The potential to produce information that can be used in decision making support for redevelopment in any city with a similar wastewater drainage system can be assumed. Traditional information methods do not support simulation/ modeling. The data used to manage the rapidly expanding infrastructure like during redevelopment are so voluminous and spatially oriented that Geographic Information Systems. Topologic chain numbers as a pipe order were generated for network segments (connected at nodes) so that flow volume increases ‘downstream’ along the network could be computed in reference to the attribute data about pipe sizes.

A study by Ouma et al, 2011 employed GIS and Multi-Criteria Analysis in landfill site selection for growing urban regions; many factors were taken care of in the locating process like transportation, water resources. Weightings were assigned to each criterion depending upon their relative importance relative magnitude of impact. The results, analyzed using neighborhood-proximity analysis, show the effectiveness of the system in the site-selection process for Eldoret Municipality (Kenya).Two hierarchies were applied and from it one can calculate marginal benefits to cost ratios, (Saaty, 1990).Marginal benefit cost analysis along traditional lines can be carried out by a arranging costs in increasing order .The very first ratio is that of alternative with the smallest cost. Databases needed for sewerage system management have been improved using GIS. During redevelopment, pipe network databases can be designed to accommodate flow volume simulations. The development of such a modeling capacity allows not only combined sewerage (storm water and wastewater) volume analysis but also prediction and scenario modeling. System objectives are thus: effective database management (storing many types of data, rapid query and retrieval capability and easy data maintenance/update). Prediction scenario modeling for decision support in management and planning.

Treating map layers as criteria in site screening and converting them to fuzzy maps according to appropriate linguistic values, resulting to a composite map obtained by intersecting all the criteria maps. The intersection of fuzzy sets is normally based on the use of the min-operator. Such that, Distance from human settlements receives the highest weight because its elements or sub criteria are primary targets to be protected from any adverse effects. It is also very natural for the public to reject a landfill site if it is located close to their homes or amenities. Therefore, the highest weight given in the preliminary screening reflects one of the attempts to avoid public resistance in the later stage of landfill development. Distance from water bodies reduces the possibility of contamination in surface water. Agricultural land and forest reserve areas are considered as protective lands. Thus, the distance from items in the natural resources group receives second priority. Optimum distance from roads is considered the third while topography receives lowest priority because landfill can be designed to fit various terrain characteristics and terrain that is clearly unsuitable is already excluded by the parameters used to define the membership function, (Charmpatheep, 1997).

Building models are key elements of a digital city concept that relates to large numbers of applications, such as urban planning, crime prevention, disaster mitigation, transportation optimization and sustainable development,(Xianfeng, 2013). The Digital Elevation Model (DEM) generation can be the base of digital terrain modeling for urban water management and analysis of sewerage flow volume. Simulations were carried out for both present and assumed future conditions, and with changed recurrence intervals specified (Yoo, 2005).

Manhole depths, pipe lengths, diameters and slopes are included in the Pima County GIS system. (Sier and Lansey, 2005). As per Rules Establishing Minimum Standards Relating to Location, Design, Construction and Maintenance of Onsite Wastewater Treatment Systems, December, 2009, For Hydrogeology, Proposals to lower the groundwater table must be reviewed by the local reviewing agency, the Michigan Department of Public Health for Slopes; Since a relatively level area is needed for the installation of a standard soil absorption system, areas with 12% or greater slope are to be avoided.

Monitoring of sewage characteristics should be undertaken on an extended timeframe. This is essential where kinetic modeling of the sewage treatment process is to be undertaken. The variations would be due to internal water usage, infiltration/inflow and trade waste loadings (Planning Guidelines for Water Supply and Sewerage, April 2010).

Economy designers want to connect the maximum number of properties with the minimum length of sewer. However there are many changing circumstances that will influence the design requirements; climate change, growth including urban creep and creep of impermeable surfaces, maintenance including change in capacity due to siltation and cleaning. Simulation process using cut and try, the stages use different models to account for the anticipated catchment changes. By adopting the factor of safety principal to distinguish between uncertainty and the expected performance, at least 80% of all public and private decision-making is based on some spatial or geographic aspects (FIG, 2001).
From ArcGIS 10 help, Weighted Overlay (Spatial Analyst) Each raster is assigned a percent age influence. The cell values are multiplied by their percentage influence, and the results are added together to create the output raster. A floating-point raster must first be converted to an integer raster before it can be used in Weighted Overlay. The Reclassification tools provide an effective way to do the conversion. Each input raster is weighted according to its importance or its percent influence. The Weight is a relative percentage. The Weighted Overlay tool allows the calculation of a multiple-criteria analysis, between several raster’s, Overlays several raster’s using a common scale and weighing each according to its importance.

Spatial variables which could potentially affect the urban growth boundary in Kisii municipality: elevation, slope, distance to urban, distance to stream, and distance to road.

Another landscape consideration that can have a strong influence on the geometry of the urban growth boundary is the existence of reserve areas where development is prohibited by law in Kisii town. The basic assumption is that humans need various developments like roads to access areas where resources will be resulting in urban change, (Tayyebei et.al, 2013).

Information about the size and nature of contributing areas can be obtained instantly. If most local governments develop their own GIS database, Database information can include land cover pattern, pipe diameter, length and slope as well as large-scale digital topographic data, (Yoo, 2005).

Sewage carries pathogenic organisms that transmit diseases to human. It contains organic matter that causes odour and nuisance problems. Where a main sewerage system has not been provided like Bouti,Nyankongo,Nyamataro, Bobaracho,part of Daraja mbili and Menyinkwa. This is evidenced by the captioned photograph in the Appendix, which shows pit latrines up on the hill and downstream in the same place they have a spring for drinking water as realized in a spring next to Daraja mbili primary school near Daraja mbili market in the study area.

METHODOLOGY

Area of Study

The study area sits within Kisii County formerly the larger Kisii District. Kisii is located in Western part of Kenya as shown in Figure 1 below, on Latitude of 0° 41’ 0 S and Longitude: 34° 46’ 0 E. As realized from the Kisii county development profile 2013 the town is surrounded by a hilly topography like that of Kionganyo 1,710m and Kiamwasi 1,785 m.

![THE STUDY AREA MAP - KISII TOWN](image)

The approach used for the database development and sewer line routing process is summarized in Figure 2. The first step involved the selection of the spatial and non-spatial factors affecting the sewer line route. Some of the factors considered included topography, surface geology, soils, roads, land use, existing sewer line, planning requirements and population densities. The geology and the soil types in the area are different thus present varying levels of construction hardships. Different cost was assigned to different soil type and the geology on the basis of ease of construction. The harder it is to dig through a particular type of rock the higher the cost. High relief terrain results in higher construction costs and increases the need for pump stations. Highly sloppy land was assigned high cost as the cost reduces as the slope reduces, thus high areas were avoided. The utilization of existing utility corridors and easements also ease the construction hardship. The nearer the sewer line is to a transportation corridor the less the disturbance to the environment and minimizes the construction cost associated with clearing of vegetation. The drainage of the area in terms of ground water sites, lakes, rivers will be taken into account in order to conserve the environment and protect the catchment areas. The population factors considered were; proximity to settlements and populated centers, in order to serve the population.
Data for the execution of this work was obtained from both primary and secondary data like Town development plans, Satellite Images; Quick bird images were collected for 2013 and topographical maps sources. Observation, questionnaires and interview were used to obtain the primary data including GPS or classical methods were also used. Remote sensing: The process includes the gathering of remote-sensing data like Satellite images: The delineated urban boundaries digitized from topographical maps 130/1 and 130/2 are then overlaid with spatial layers in GIS after digitizing to prepare input and output data; Preparation and running of models and the filtered optimal areas based on the AHP questionnaire to assign the conditional tool in the model depending on the priority vector realized from table 2 the matrix for 8, 9 and 10 as per the personal interviews with engineer,( Engineer James Manyara and the water engineer respectively).

The layer (contour line minor) was projected into the project coordinate system (Arc 1960 UTM Zone 36S, Datum Arc 1960). The projected layer were then clipped using the Kisii Municipality boundary shape file as per Figure 2 above to get contour of the study area. Manhole points were also digitized from the existing topographical and urban planning maps and the new ones obtained by using a hand held GPS downloaded using map source software. Later clipped to get only those in the area of interest. Similarly, digital elevation model generated through the Global Mapper software to obtain contour data which was also clipped to the study area using the municipality boundary layer. In slope generation, the slope was identified (gradient, or rate of maximum change in z-values) from each cell of a raster surface. Slope values ranges from 0 to 90 degrees. For percent rise, the range is 0 to near infinity. A flat surface (with no gentleness in terms of slope) is 0 percent (%). A 45 degree surface is 100 percent and as the surface becomes more and more vertical, the percentage rise becomes increasingly larger. The generated slope output was reclassified using the reclassify tool into 10 classes of equal intervals. The higher the ranks the more suitable an area is for sitting the underground substation for sewerage network while lower ranks for very steep areas that are unsuitable for selection.

Re-classed slope was weighted using the Weighted Overlay tool with an evaluation scale (common measurement scale) of 1 to 10 by 1 to cater for the 10 equal classes used in the reclassification process. Each class was weighted according to its importance which generated Cost Surface based on expert views.

Results and Discussions

Figure 3 below summarizes the population trends in Kisii town and highlights the rapid population increase in the area. The increase in population demands a corresponding improvement in sewer services.
From the analysis of the data resulted in table figure 4 which implied that the process of accessing data is very slow and many files go missing. Whereby the highest number of respondents (25.6%) reported of the process of being slow and (22.2%) reported of the current process being expensive and whereas (23.9%) reported of missing files among the bottlenecks.

Figure 4: The bottlenecks of the current process

These results show that the current process of accessing data is not effective and therefore the need for the data to be computerized for easy accessibility. Weights were calculated together with the consistency ratio. The results for each category of respondents and the corresponding consistency ratio are illustrated in this section. These Pair wise comparisons were generated based on scale of relative suitability according to Saaty (1980) From the expert response the optimal areas were ranked as kisii town (0.35), Daraja mbili (0.57) and other areas 0.08. From the weights based on pair wise comparison kisii town had a weight of 0.35, meaning that it has 35% influence, while Table 2: Pair wise comparison

<table>
<thead>
<tr>
<th></th>
<th>Kisii Town</th>
<th>Daraja Mbili</th>
<th>Others</th>
<th>PRIORITY VECTOR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kisii</td>
<td>1</td>
<td>1/3</td>
<td>9</td>
<td>0.35</td>
</tr>
<tr>
<td>Town</td>
<td></td>
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<tr>
<td>Daraja</td>
<td>3</td>
<td>1</td>
<td>5</td>
<td>0.57</td>
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<td>Mbili</td>
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<tr>
<td>Others</td>
<td>1/9</td>
<td>1/5</td>
<td>1</td>
<td>0.08</td>
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Daraja mbili has a weight of 0.57 meaning that it has 57% influence and other areas (0.08) meaning that they had a weight of 8%. as per Table 2.

Datasets including land use slope, population, and roads were clipped using the study area polygon, the Digital Elevation Model as shown on figure 6 was clipped to the study area, slope was then derived as per figure 7, followed by reclassification and adding the results to the weighted overlay table. The slope and population data were clipped to the study area, updated to the database, rasterized, reclassified then added to the weighted overlay table. Other datasets were clipped to the study area extents; a union was then done with the study area, updated both to the database, reclassified and added to the weighted overlay table.

Figure 5: Generated DEM and Contour Layer

The results for reclassification are shown and illustrated using maps in the following section. Deriving datasets, such as slope, was the first step when building the sewer line route suitability model where each cell in the study area has a value for each input criteria. All the derived data sets need to combine so as to create a suitability map that will identify the potential locations for the new sewer route. The values in the datasets derived in previous steps were all floating-point, continuous datasets, categorized into ranges, and they had to be first reclassified so that each range of values is assigned. They were first reclassified to a common measurement scale, 1 to 10 for slope based on figure 5, as per figure 6. Figure 7 for population was generated based on population census of 1999 and 2009. The common measurement scale determined how suitable a particular each cell is for building routing a sewer route.

Figure 6: Re classified slope
Higher values indicate less suitable locations for the route. Using the Weighted Overlay tool, the weight values calculated using analytical hierarchical process was assigned to each dataset. All the above processes were done using a model builder. From the model, Cost Distance tool was used to record the accumulated cost of getting from each cell to the nearest source while the Cost path Tool was used to produce an output raster that recorded the least-cost path or paths from selected locations to the closest source cell defined within the accumulative cost surface, in terms of cost distance. The Output cost Back link which aided in defining the direction or identify the next neighboring cell (the succeeding cell) along the least accumulative cost path from a cell to reach its least cost source. This recorded the least-cost path or paths from selected locations to the closest source cell defined within the accumulative cost surface, resulting to map on figure 8.

The two main layers used in the suitability mapping of the sub-station site selection were, the re classed population and re classed slope as shown above on the weighted overlay tool. The two criteria were accorded equal influence of 50% each. These were overlaid to generate a cost surface map as Figure 9.

Market centers were used as the conveyor points and the optimal area as the convergence points; resulting from running the cost path tool using the output cost distance element. The analysis was based on market centers as the conveyor points and the optimal area as the convergence points; resulting from running the cost path tool using the output cost distance element as figure 10.
Raster to poly line tool was used to generate the proposed sewer line, by running it aided in Converting raster dataset in figure 10 above to poly line feature resulting to a proposed sewer line as per Figure.11.

Figure 10: Output cost path layer

Figure 11: New Proposed Sewer Line Network for Kisii Municipality

CONCLUSIONS AND RECOMMENDATIONS

The current sewer line and sewer infrastructure in Kisii is outdated and overstretched leading to environmental degradation and health risks. Kisii town, now a county headquarters therefore requires developing a sewerage management information system to guide future development.

To achieve this objective, primary and secondary datasets including Kisii Town development plans, High resolution satellite images, topographical maps, population data, questionnaires based interviews and GPS mapping were used in GIS environment to analyze and model the sewer system. The Analytical Hierarchical Process (AHP) which relies on the judgment of experts in assigning weights was used in optimizing the location of the proposed new sewer line. The model developed incorporated sewer line length, topography, land use, soil types, and populated areas, among others to identify an optimal sewer line location. Analytical Hierarchical Process (AHP) was used as a means to determine the relative preference of each factor.

Results show that seventy percent of the available manual data is not accessible, implying also that accessing the data is very slow and expensive and substantial numbers of files are either missing or misplaced. Questionnaire analysis results indicate that majority of those interviewed would prefer the computerization of the sewage information department just to mention a few among many who have population increase, this demands an increase in infrastructure and other utilities to cater for the overwhelming population pressure. Results indicate that the Current sewer line cannot be relied upon for future development while GIS techniques could be applied successful in order to select optimal sites for sewer management and generate optimal sewer lines. This confirms that modeling using geospatial tools could help decision makers at relevant agencies and authorities to combat various developmental problems.

This study therefore outlines the powerful capabilities of GIS techniques in handling digital data to select optimal sites sewer management for the ever growing Kisii County that is in need of more land that is not available. Hence there is desperate need of scientific and modern techniques that will help decision makers at relevant agencies and authorities to combat waterborne disease outbreak and save resources especially time and money in exploring suitable sites for waste water treatment in the county, sub counties.

Recommendations

It is recommended that GIS techniques be adopted for routing purposes and not only for sewer line but for other different linear problems such as pipelines, and power lines by the Government of Kenya in order to save on operational and maintenance cost, protect the environment and reduce accidents. When routing a pipeline or power line for transmission of electricity, the same model can be used with a variation of the data sets and the rules applied to the variables. Rail lines, water pipes, road can be routed using the model developed. In order to improve the results of this study it’s recommended that land ownership dataset and costing used for an existing sewer line be incorporated for further analysis. The cost of land along the proposed route should be determined in order to give an indication of compensation. Furthermore the model can be enhanced by adding the other variables that maximizes on public and government land. It’s also recommended that an independent interface should be developed independent of ArcGIS for incorporating data in the model and executing it. The independent interface will enable non GIS professionals to use the model. The current model must be executed within ArcGIS model builder by an expert with knowledge of the model builder.

Finally, it is recommended that fieldworks must be carried out on the proposed optimal route for further investigations and fine tuning the route in order to ensure that there are no conflicting interests in the study that are not shown by the available GIS research data. The study was limited by the data available. By carrying out ground survey smaller details that were not discernable within the data resolution can be taken into account.

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APPENDIX: Photo (Pit Latrine/Spring of Water); Daraja Mbili_Kisii

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