GC Revista Nacional de Gerenciamento de Cidades
National Journal of City Management

ISSN 2318-8472, v. 12, n. 87, 2024

Analysis of alternative sewage systems for a teaching and research institution in Rio Verde, Goiás

Vanessa Petronília Alves
Master, IFGoiano, Brasil
vanessa_petronilia@hotmail.com

Edio Damásio da Silva Júnior
Doctor, IFGoiano, Brasil
edio.damasio@ifgoiano.edu.br

Devaney Ribeiro do Carmo
Doctor, UNESP, Brasil
devaney.carmo@unesp.br

Submissão: 01/07/2024
Aceite: 09/08/2024
ALVES, Vanessa Petronília; SILVA JÚNIOR, Edio Damásio da; CARMO, Devaney Ribeiro do. Análise de alternativas de sistemas de esgotamento sanitário para instituição de ensino e pesquisa em Rio Verde, Goiás. **Revista Nacional de Gerenciamento de Cidades** , *[S. l.]*, v. 12, n. 87, 2024. DOI: 10.17271/23188472128720245267
Disponível em:
https://publicacoes.amigosdanatureza.org.br/index.php/gerenciamento_de_cidades/article/view/5267

GC Revista Nacional de Gerenciamento de Cidades
National Journal of City Management

ISSN 2318-8472, v. 12, n. 87, 2024

Análise de alternativas de sistemas de esgotamento sanitário para instituição de ensino e pesquisa em Rio Verde, Goiás

RESUMO
Dentre os serviços do saneamento básico, a coleta e o tratamento do esgoto são importantes para a saúde. É de responsabilidade dos empreendimentos coletivos a implantação e manutenção do esgotamento sanitário no interior de sua propriedade. O IFGoiano campus Rio Verde teve pouca atualização no sistema de esgotamento sanitário no decorrer dos anos, e conta com uma rede antiga de cerâmica e de fossas rudimentares as quais contém rachaduras e degradações e, possivelmente estão contaminando o solo. Existem algumas alternativas possíveis para a atualização do sistema de esgotamento sanitário do campus. Uma delas é estabelecer uma rede coletora nova que será interligada na rede pública existente da cidade. Outra opção seria setorizar o esgoto em sistemas descentralizados com a aplicação conjunta de tanques sépticos e wetlands. Mediante a isso, este trabalho visa analisar a viabilidade econômica de cada alternativa proposta de adequação do sistema de esgotamento sanitário do campus, sendo que foi possível observar que a rede centralizada é um sistema com mais confiabilidade dos usuários, porém, mais oneroso, totalizando um custo de execução de R$ 1.849.549,35. Já a rede descentralizada é um sistema ainda não tão popular, porém menos oneroso, totalizando um custo de execução de R$ 1.382.480,23. Além desses valores a rede centralizada conta com uma estimativa de custo de operação e manutenção de R$ 13.187.424,57 no decorrer de 20 anos, que torna a escolha por esta alternativa inviável, pois os custos de operação e manutenção da rede descentralizada são de R$ 44.697,60.
PALAVRAS-CHAVE: Saneamento básico. Águas residuárias. Viabilidade econômica.

Analysis of alternative sewage systems for a teaching and research institution in Rio Verde, Goiás

ABSTRACT
Among basic sanitation services, sewage collection and treatment are important for health. It is the responsibility of collective enterprises to implement and maintain sewage systems within their property. The IFGoiano Rio Verde campus has had little updating of its sewage system over the years and has an old ceramic network and rudimentary pits which contain cracks and degradation and are possibly contaminating the soil. There are some possible alternatives for upgrading the campus sewage system. One of them is to establish a new collection network that will be interconnected to the city's existing public network. Another option would be to sector sewage into decentralized systems with the joint application of septic tanks and wetlands. Therefore, this work aims to analyze the economic viability of each proposed alternative for adapting the campus's sewage system, and it was possible to observe that the centralized network is a system with greater user reliability, however, more costly, totaling a execution cost of R$ 1,849,549.35. The decentralized network is a system that is not yet as popular, but less expensive, totaling an execution cost of R$ 1,382,480.23. In addition to these values, the centralized network has an estimated operating and maintenance cost of R$ 13,187,424.57 over 20 years, which makes the choice for this alternative unfeasible, as the operating and maintenance costs of the decentralized network are of R$ 44,697.60.

KEY-WORKS: Sanitation. Wastewater. Economic viability.

Análisis de alternativas de sistemas de alcantarillado sanitario para una institución de enseñanza e investigación en Rio Verde, Goiás

RESUMEN
Entre los servicios de saneamiento básico, la recolección y el tratamiento de aguas residuales son fundamentales para la salud. Es responsabilidad de las instituciones colectivas implementar y mantener el sistema de alcantarillado sanitario dentro de sus propiedades. El campus Rio Verde del IFGoiano ha tenido pocas actualizaciones en su sistema de alcantarillado sanitario a lo largo de los años y cuenta con una red antigua de cerámica y fosas rudimentarias, que presentan grietas y degradaciones y posiblemente están contaminando el suelo. Existen algunas alternativas viables para la modernización del sistema de alcantarillado del campus. Una de ellas es establecer una nueva red de recolección conectada al sistema público existente en la ciudad. Otra opción sería sectorizar las aguas residuales mediante sistemas descentralizados con la aplicación conjunta de tanques sépticos y humedales construidos (*wetlands*). Este estudio tiene como objetivo analizar la viabilidad económica de cada una de las alternativas propuestas para la adecuación del sistema de alcantarillado sanitario del campus. Se observó que la red centralizada es un sistema más confiable para los usuarios, pero más costoso, con un costo de ejecución de R$ 1.849.549,35. Por otro lado, la red descentralizada es un sistema menos popular pero más económico, con un costo de ejecución de R$ 1.382.480,23. Además, la red centralizada tiene un costo estimado de operación y mantenimiento de R$

ISSN 2318-8472, v. 12, n. 87, 2024

13.187.424,57 durante 20 años, lo que hace que esta alternativa sea inviable, ya que los costos de operación y mantenimiento de la red descentralizada ascienden a solo R$ 44.697,60.

PALABRAS CLAVE: Saneamiento básico. Aguas residuales. Viabilidad económica.

1. INTRODUCTION

Basic sanitation aims to provide assistance in relation to water supply, sewage collection and treatment, solid waste disposal and rainwater drainage. Aiming to improve sanitation in Brazil, the National Basic Sanitation Plan (PLANSAB) was established, which defined universal access to basic sanitation services as a social right that must be achieved by 2030 (BRK, 2019).

Among the basic sanitation requirements, the collection and treatment of sewage are also important for the health of human beings, as when sewage is not collected and is disposed of incorrectly, it can cause the proliferation of diseases and harm nature.

Demand for the Rio Verde campus of the Federal Institute of Goiano (IFGoiano) has increased over the years, however, there has been little updating of the campus's sewage system.

To be able to resolve the issue of campus sewage, there are some possible alternatives for updating the sanitary sewage system (SES). One of them is to establish a new collection network interconnected with the city's existing public network. A second option would be to sector sewage into decentralized systems with the application of septic tanks combined with wetlands, which would be placed in strategically selected locations.

Therefore, this work aims to propose suggestions for adapting the sanitary sewage system of the Rio Verde campus of IFGoiano to serve the personnel who attend the campus, promoting knowledge that in the future can help the institution's management in the implementation of an adequate sanitary management system.

2. OBJECTIVE

The general objective of this research is to evaluate alternatives of sanitary sewage systems for the Rio Verde Campus of IFGoiano and to indicate the best economic and technical options for the institution's managers.

3. METHODOLOGY

To carry out the research, it was necessary to carry out the following steps: defining the study area by surveying the campus's current sewage structure; collecting existing data on the object of study with a planialtimetric survey of the area and the quantitative population served in the project; suggestion of campus sewage management alternatives, with alternative I being the centralized sewage network (connected to the public network) and alternative II being the individual decentralized sewage system (each building has its own collection network and treatment); comparative analysis of campus sewage management alternatives by carrying

ISSN 2318-8472, v. 12, n. 87, 2024

out a technical comparison of the suggested solutions; evaluating the solutions taking into account the economic aspects.

3.1 Study area

The IFGoiano campus Rio Verde - GO is located in the southwest of the state of Goiás located on the São Tomaz farm, Sul Goiana highway, km 01, rural area, and has 2,060,600 m². Its repertoire includes technical courses, higher education courses and postgraduate courses. The Campus also carries out various activities in the areas of teaching, research and extension. It has around 4,419 students, 128 teachers and 105 administrative technicians (BRASIL, 2017b).

The Institute has been expanding its infrastructure with more than 31 thousand m² (BRASIL, 2017c). Of these new works, some were implemented independently of the rest of the existing campus, meaning that the sanitary sewage remained untreated, and others were built using the existing network.

The existing sewage network of the IFGoiano Rio Verde campus is an old network of ceramics and rudimentary pits that, in addition to not meeting current demand, contain cracks and degradation that are possibly contaminating the soil, and the campus' water supply comes from the underground. Wastewater from toilets, laboratories and washing machines and equipment is generated on the campus. Furthermore, the campus had a sewage treatment plant, however, it is currently deactivated.

IFGoiano – Rio Verde is bordering the Gameleira neighborhood, among other adjacent neighborhoods that are provided with a public sewage network operated by BRK Ambiental, but are not served by this sewage network.

3.2 Data collection from the study object

To collect data from the object of study, a planialtimetric survey carried out by the company ASPLAN was used, which made it possible to visualize the contour lines and the location of the buildings existing at the Institute.

To calculate the flow rates, on-site visits were carried out to the constructed buildings in order to analyze how the actual sewage disposal of each building was, as well as to find out how many effluent evasion points currently exist and how many people frequent each building. To assist in the survey, a data collection spreadsheet was created containing the name of the building, the type of use of the building, the area, the existence of a sewage network, the number of bathrooms and the number of people.

For the population calculation, it was established that the scope of the plan would be twenty years and the year in which the system would start operating would be 2026. For the population estimate of the collector sections, the number of people was added according to the buildings served in each section of the network. The population projection calculation was used with the collected data, the arithmetic projection calculation technique was chosen, which according to Tsutiya (2006) assumes a constant growth rate for the following years based on known data.

ISSN 2318-8472, v. 12, n. 87, 2024

The years used were the creation of the campus, in 1967, with an equivalent population of 0, the year 2023 used to carry out the survey, with the equivalent population according to the survey and the year 2046 as the final year of the estimated population.

3.3 Sewage management alternatives

3.3.1 Alternative I – centralized sewage system

Alternative I involve a centralized collection network that serves as many campus buildings as possible, aiming for interconnection with the public network. Topographic criteria were used to choose the buildings that would be connected to the centralized network in a way that more distant buildings were not included, aiming for greater savings. For Alternative I, it was considered that the service provider that manages sewage in Rio Verde is the company BRK. The relevant standards of the company itself and management bodies were used. In the calculations, the flow rates of each section and the planialtimetric survey were considered to size the network.

Based on the data collected, a layout of the sewage network was created using the AUTO CAD 2020 and Google Earth software, following NBR 9649 of 1986. Taking into account that the service provider will collect the sewage in a single connection (AMAE, 2021), it was considered in the project that the interconnection of the internal sewage network with the public sewage network will take place at the lowest point of the land, according to the level curves analyzed, this final point being at an altitude of 487.55 m.

The design flows for each section and block of the network were calculated using a respective spreadsheet for each alternative. To calculate the flow, the final domestic flow formula was used according to Tsutiya and Sobrinho (2011).

For the sewage contribution, the per capita generation of 50 L/per.day was used in accordance with NBR 7229 in the item that deals with temporary occupants in schools (ABNT, 1993). As for the other coefficients, in accordance with NBR 9649, in the absence of proven local data from research, the following values are adopted (ABNT, 1986):

- Return coeficiente equal to 0,8;
- Maximum daily flow coefficient equal to 1,2;
- Maximum hourly flow coefficient equal to 1,5;
- Infiltration contribution rate between 0,05 and 1,0 (L/s*km). Due to the lack of data, the rate of 0,5 L/s*km was used to lay out the network.

The sanitary sewage network Ws sized using the calculated flows, in accordance with NBR 8160 (ABNT, 1999), which has the diameter equation as its main formula.

3.3.2 Alternative II – descentralized sewage system

Alternative II consists of an individual decentralized sewage system, where each building has a collection network and its own treatment, with septic tanks being considered as primary treatment and constructed wetlands as secondary treatment. In this system, it would be

GC Revista Nacional de Gerenciamento de Cidades
National Journal of City Management

ISSN 2318-8472, v. 12, n. 87, 2024

possible to reuse waste from sanitary effluents treated within the campus itself, emphasizing sustainability and economy. For the calculation, the volumes of septic tanks and constructed wetlands were considered. The positioning of possible septic tanks and wetlands built in a network layout was made. To calculate the septic tank, Equation 4 was used according to NBR 7229 (ABNT, 1993), while Equation 5 was used to calculate the wetlands, according to Table 1.

Table 01 – Representation of the formulas used in the design of the centralized sewage network.

Equation formula	Equation Numbering
V = 1000+N.(C.T+K.Lf)	(4)
V = Q. (Ca – Ce) / (Kt.Ce)	(5)

Source: ABNT (1993), Kadlec e Wallace (2005).

Being that:
V = useful volume of the septic tank (L);
N = number of people;
C = sewage generation per capita (L/per.day); 50 L/per.day;
T = hydraulic detention period (day) 1 day;
K = digested sludge accumulation rate in days, equivalent to the fresh sludge accumulation time; 57 days, referring to the interval between cleanings of 1 year with an ambient temperature greater than 20ºC;
Lf = fresh sludge contribution (L/per.dia); 0,20 L/per.day;
C_a= input concentration in terms of DBO (mg BOD/day); 300 mg/L;
C_e= outlet concentration in terms of DBO (mg BOD/day); 60 mg/L;
Q = flow (m^3/day)
Kt = (day^{-1}) organic matter degradation coefficient = $1{,}03.1{,}06^{(t-20)}$, with t being the average temperature of the coldest month, considering that this temperature for the city of Rio Verde in the State of Goiás is approximately 21.1ºC in the month of June (CLIMATE, 2023).

3.4 Comparative analysis of alternatives

3.4.1 Economic analysis

An evaluation of the alternatives was carried out taking into account the economic aspects. For this evaluation, two budgets were prepared, one for each suggested alternative. The budgets were based on the SINAPI (National System of Research on Costs and Indices of Civil Construction) table. The budget considered all the labor and material costs necessary for the correct execution of the project in the internal part of the Campus, since according to AMAE (2021), the internal networks of housing units similar to condominiums will be installed exclusively by the respective persons responsible for the project.

An operation and maintenance budget was included for all alternatives, taking into account a period of 20 years. The amounts charged by the service provider for registering and connecting the establishment's sewage system to the public network were also considered. This period also includes the fees charged by the service provider for the volume of sewage

ISSN 2318-8472, v. 12, n. 87, 2024

discharged into the public network. According to AMAE (2021), the value of the sewage volume fee is calculated according to the water consumption carried out by the enterprise. However, if the user has an alternative source of water supply, the service provider may install a water meter in this alternative source for the purpose of measuring water consumption. To calculate the fees that would be charged by the service provider, the "Table of prices and terms of service" approved by AMAE/RIO VERDE was used.

3.4.2 Technical analysis

A technical evaluation of the alternatives was carried out considering the construction, maintenance and operation aspects. The level of difficulty of implementing each alternative was compared. The acceptability of the population served was also evaluated, as well as the sanitary safety and generation of odors. It was analyzed whether any special intervention would be necessary in the alternatives. All these characteristics were analyzed and compared for each alternative in a discursive way in the results.

4 RESULTS AND DISCUSSION

4.1 Alternative I – centralized sewage system

For Alternative I, a network layout was created on Google Earth. This layout included 56 manholes (PV) and the collector sections. Google Earth and AutoCAD software were used to verify the distances of the sections, and the sum of these distances was 3,144.09 m. The number of people served in each section was separated and entered into the sum of sections in the spreadsheet. With this data, it was possible to dimension the diameter of the collectors, adopting a commercial diameter of 100 mm for all sections, since the calculation diameter of these sections had reached a result smaller than the minimum commercial diameter of 100 mm.

4.1.1 Economic analysis

Executive budget

In the preliminary services, specific compositions were considered for the values of mobilization and demobilization of equipment and personnel, in addition to the installation of the construction site and administrative personnel (DNER, 1997). According to the TCU (2013), expenses with local administration, construction site, mobilization/demobilization must be broken down in the budget spreadsheet as direct costs of the work.

In the item of mobilization of equipment and people, 5 days with 8 hours worked per day were considered to mobilize a hydraulic excavator and a dump truck to the construction site at a value of R$ 402.44 per hour, the same was considered for demobilization.

According to ABNT (2023), the construction site is intended to support the services to be performed and must have the capacity to house the team responsible for providing the

ISSN 2318-8472, v. 12, n. 87, 2024

services, store the material to be used and contain offices for the construction team. For this item, the installation of an office, a warehouse, a cafeteria, a bathroom with changing room and a water tank was considered in order to comply with regulatory standard 24 (BRASIL, 2022b). The useful areas of each location on the construction site were calculated taking into account the provisions of NBR 12284 (1991), and their composition is as follows:

- 27 m² of office in plywood at R$ 1,122.49 per m²;
- 18 m² of warehouse in plywood at R$ 887.80 per m²;
- 40 m² of cafeteria in plywood at R$ 573.91 per m²;
- 20 m² of toilet and changing room in wood at R$ 973.41 per m²;
- 1 elevated water tank on wooden support at R$ 6,327.52 per unit.

For the administration item, 40 hours worked per week, 4 weeks per month, over a period of 12 months were taken into consideration with the following employees and their respective salaries according to SINAPI (2023):

- Pipe installer (R$ 3,095.63/month);
- Pipelayer (R$ 2,807.56/month);
- Occupational safety technician (R$ 27.62/h);
- Surveyor (R$ 3,698.18/month);
- Construction foreman (R$ 6,954.46/month);
- Civil engineer (R$ 18,216.41/month);
- Storekeeper (R$ 3,708.72/month).

The results can be seen in Table 2.

Table 02 – Budget for preliminary services of the centralized sewage network.

Description	Amount	Unit	Unit value	Total value
Mobilization	40	H	R$ 402,44	R$ 16.097,60
Desmobilization	40	H	R$ 402,44	R$ 16.097,60
Construction site	1	un	R$ 95.039,75	R$ 95.039,75
Administration	12	meses	R$ 42.900,16	R$514.801,92
TOTAL				**R$ 642.036,87**

Source: Authoress (2024).

For the collection network, the following services were considered: excavation, cargo transportation, trench shoring, trench bottom preparation, pipe laying, backfilling, and installation of manholes. For trenches with a depth greater than 1.25 m, the use of mechanized excavation is recommended. To calculate the mechanized excavation, the sum of the lengths of the sections was considered, resulting in a total of 3,144.09 m. Since the composition in SINAPI is in m³, a trench width of 0.80 m and a depth of 1.50 m were considered, to meet the requirements of regulatory standard 18 (BRASIL, 2022a) and NBR 17015 (ABNT, 2023), resulting in a total of 3,772.90 m³. This calculation was also used for the soil transportation item and for backfilling, as can be seen in Table 3.

ISSN 2318-8472, v. 12, n. 87, 2024

Table 03 – Budget for installation services of the centralized sewage collection network.

Description	Amount	Unit	Unit value	Total value
Mechanized trench excavation	3772,90	m³	R$ 10,67	R$ 40.256,86
Loading, maneuvering and unloading of soils	3772,90	m³	R$ 9,26	R$ 34.937,07
Trench shoring	9432,26	m²	R$ 22,65	R$ 213.640,96
Trench bottom preparation	251,53	m³	R$ 277,35	R$ 69.760,96
Tube PVC	3144,09	m	R$ 17,42	R$ 54.769,96
Mechanized backfill	3772,90	m³	R$ 23,00	R$ 86.776,75
Base for circular manhole	57	un	R$ 2621,31	R$ 149.414,67
Supply and installation of cap	57	un	R$ 629,09	R$ 35.858,13
TOTAL				**R$ 685.414,98**

Source: Authoress (2024).

According to NR 18, Brazil (2022a), trench shoring must be carried out for excavations with a depth greater than 1.25 m. The trench shoring item is given in m² in SINAPI, using the length of 3,144.09 m multiplied by the depth of 1.50 m, and having its value doubled, since the shoring is done on both sides of the trench.

To calculate the preparation of the trench bottom, the same length of 3,144.09 m multiplied by the width of 0.80 m and also by the height of the sand bed of 0.10 m was considered. To calculate the quantity of PVC pipe, the value of the sum of the length of the sections of 3,144.09 m was considered.

To calculate the number of manholes, the quantity of 57 units used in the network layout with pre-defined dimensions according to SINAPI was considered, using an estimate based on the calculated design flow rates. The composition of the manhole item did not include the installation of caps, so the quantity of caps was placed in a separate item, and for this calculation the same 57 units used in the network layout were considered.

For the reconstructions, the reconstruction of asphalt paving, grass and curb were considered according to the excavations as per the layout of the centralized sewage network as per Table 4. For asphalt paving, the sum of the amount of paving area that will have to be demolished in the sections that had to cross the roads was considered, totaling 660 m multiplied by the excavation width of 0.80 m. For the reconstruction of grass, the sum of the sections that were excavated in places where there was grass vegetation was calculated, totaling 2,484.09 m multiplied by the excavation width of 0.80. For the curb, the sum of the amount of curb length that will have to be demolished in the sections where intervention was necessary was considered, totaling 37 m.

Table 04 – Budget for the restoration services of the centralized sewage collection network.

Description	Amount	Unit	Unit value	Total value
Asphalt recomposition	52,80	m²	R$ 1897,02	R$ 100.162,66
Grass restoration	1987,27	m²	R$ 17,04	R$ 33.863,11
Curb restoration	37,00	m	R$ 35,42	R$ 1310,54
TOTAL				**R$ 135.336,31**

Source: Authoress (2024).

ISSN 2318-8472, v. 12, n. 87, 2024

TCU ruling 2622 of 2013 is the only document that brings a consensus on the BDI for public works. In this research, the percentages of this ruling were used, and to finalize the calculation of the executive budget, a BDI of 26.44% was used, referring to the third quartile of the reference values for public budgets in the construction of water supply networks, sewage collection and related constructions (TCU, 2013). Resulting in a BDI of R$ 386,761.19. Totaling the final budget at a value of R$ 1,849,549.35, as can be seen in Table 05.

Maintenance and operation budget

In order to implement a centralized sewage network, the appropriate steps must be taken in the service provider's registration department. These steps have fees that were considered in this research based on the price and deadline table in force for the municipality of Rio Verde - GO. The operating fees considered the costs for implementing the collection network, as can be seen in Table 05.

Table 05 – Values of the operating fees for the centralized sewage network.

Description	Total value
Sewer connection feasibility study (AVTO)	R$ 1.428,81
Design analysis of sewage systems for sewage collection networks	R$ 1.194,99
Inspection of projects	R$ 550,37
Environmental technical inspection	R$ 1.073,68
Environmental technical opinion	R$ 628,01
Technical certificate for work or project issued	R$ 83,11
TOTAL	**R$ 4.958,97**

Source: Authoress (2024).

It is necessary to note that the values in Table 05 do not include the fees if there are modifications requested in the submitted project, nor the tariff fees arising from the generation of sewage, which are considered in Table 06, as in this work these fees were estimated as maintenance fees for a period of 20 years.

Table 06 – Values of maintenance fees for the centralized sewage network.

Description	Rate	Monthly sewage generation	Period	Total value
Collection, removal and treatment of sewage for public buildings	R$ 11,06/m³	4.966,27 m³	240 months	**R$ 13.182.465,60**

Source: Authoress (2024).

To estimate the sewage consumption generated in Table 06, the flow rate was multiplied by the number of seconds in the month, in this case it is estimated 2,592,000 seconds per month multiplied by the resulting flow rate in the last PV of the centralized sewage collection network route of 1.916 L/s, totaling 4,966,272 liters of sewage. Therefore, taking into account the 20-year project period, the cost of implementing the centralized sewage system was estimated at R$ 15,036,973.92.

ISSN 2318-8472, v. 12, n. 87, 2024

4.1.2 Technical analysis

The topography of the land has a favorable slope in the direction of final disposal, and a route was chosen that would involve fewer interventions in the areas where the institute's users circulate, making them less bothered by the disruptions generated during the implementation. The system has high social acceptance among users, as it is considered a consolidated alternative for the collection, transportation and effective treatment of sewage. Since this type of work is carried out in conjunction with the campus's operation, greater attention must be paid to all safety requirements, so that campus visitors do not suffer accidents. In this alternative, no special intervention was necessary.

One disadvantage of this alternative is the execution time, which takes about a year for the system to be fully operational until the work is completed. Another disadvantage is the response time from the service provider to approve the system, since they must evaluate the project and decide whether or not to include any necessary improvements. A third disadvantage is that all bureaucratic procedures must be followed for the service to be fully executed, since the bidding process must be complete.

One advantage of this system is the possibility of including a building that is not being serviced or a future building that could be connected to the network later, since the dimensioning took into account a gap in relation to the collector diameter. Another advantage is the service provider's certification regarding the design and execution of the sewage collection network, which provides greater sanitary safety, in addition to the fact that the generation of odors from this alternative is minimal.

4.2 Alternative II – decentralized sewage system

For Alternative II, a network layout was created on Google Earth. This layout positioned 32 UDs and 21 PVs. In this alternative, Google Earth and AutoCAD software were also used to verify the distances of the sections, and the sum of these distances was 749 m. The number of people served in each UD was separated and inserted into the sum of sections in the spreadsheet. With this data, it was possible to dimension the diameter of the collectors, adopting a commercial diameter of 100 mm for all sections, since the calculation diameter of these sections had reached a result smaller than the minimum commercial diameter of 100 mm. It was also possible to calculate the volumes of the septic tanks and wetlands.

4.2.1 Economic analysis

Executive budget

In the preliminary services, the values for mobilization and demobilization of equipment and personnel were considered, in addition to the installation of the construction

ISSN 2318-8472, v. 12, n. 87, 2024

site and administrative personnel, exactly the same as the values for Alternative I, as it refers to the same area of the campus to be served. This value is a total of R$ 642,036.87.

Since the septic tank system also involves excavation, the same initial work procedures as for the centralized system were considered, which are the services of excavation, cargo transportation, trench shoring, trench bottom preparation, pipe laying, backfilling and installation of manholes. For the specific use of this system, which is different from the centralized system, the supply and installation of a septic tank and water tanks were considered, in addition to the supply of gravel 1 and planting of ornamental trees.

To calculate the mechanized excavation, the sum of the length of the sections was considered, resulting in a total of 749 m multiplied by the trench width of 0.80 m and a depth of 1.50 m, added to the volume of 297.537 m³, referring to the excavation volume of the wetlands and also to the volume of 63.224 referring to the excavation volume of the septic tanks, resulting in a total of 1259.56 m³. This calculation was also used for the soil transportation item, as per Table 07.

Table 07 – Budget for installation services of the decentralized sewage collection network.

Description	Amount	Un	Unit Value	Total value
Mechanized trench excavation	1.259,56	m³	R$ 10,67	R$ 13.439,51
Loading, maneuvering and unloading of soils	1.259,56	m³	R$ 9,26	R$ 11.663,53
Trench shoring	2.308,71	m²	R$ 22,65	R$ 52.292,35
Trench bottom preparation	59,92	m³	R$ 277,35	R$16.618,81
Tube PVC	749,00	m	R$ 17,42	R$ 13.047,58
Mechanized backfill	898,80	m³	R$ 23,00	R$ 20.672,40
Base for circular manhole	21	un	R$ 2621,31	R$ 55.047,51
Supply and installation of cap	21	un	R$ 629,09	R$ 13.210,51
Supply and installation of septic tank	56	un	R$ 1500,00	84.000,00
Supply and installation of 500L water tank	16	un	R$ 225,00	3600,00
Supply and installation of 500L water tank	11	un	R$ 354,00	3894,00
Supply and installation of 500L water tank	143	un	R$ 969,00	138567,00
Planting vegetation	128	un	R$ 60,18	7703,04
British 1	37,19	m³	R$ 198,55	7384,49
TOTAL				**R$ 441,141.11**

Source: Authoress (2024).

For the trench shoring item, the length of 749 m was used multiplied by the depth of 1.50 m, and having its value doubled, added by the wetland shoring area, making a total of 2,308.71 m². For the trench bottom preparation item, the same length was considered multiplied by the width of 0.80 m and also by the height of the sand bed of 0.10 m.

To calculate the PVC pipe, the length of the sections of 749 m was considered. For the backfill, the sum of the length of the sections multiplied by the height of 1.50 m and the width of 0.80 m was considered, totaling 898.820 m³. For the manholes and caps, the number of manholes was considered, which will be a total of 21 units.

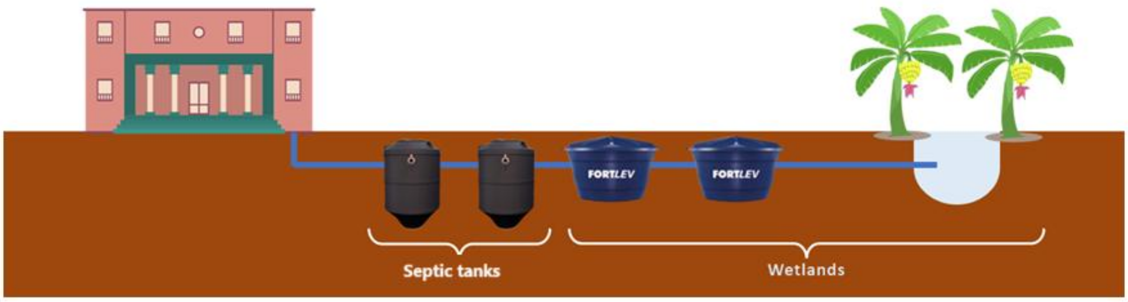
The commercial values of the Fortlev brand were considered, as it is a consolidated brand and already contains in its product line the items that make up a sewage treatment module, and for this purpose the volume was divided into commercial volume units. The

ISSN 2318-8472, v. 12, n. 87, 2024

commercial units adopted were 1500L for the septic tank and 500 L, 1,000 L and 2,000 L for the water tanks used in the wetlands system, making it necessary to associate more than one unit to meet the volume of the UD.

In the vegetation planting item, the planting of 4 banana trees for each UD was considered. According to Tonetti (2018), the banana circle is an excellent alternative for treatment and final disposal, since the water and nutrients from the sewage will be consumed by the banana trees, while the organic remains will be degraded by the microorganisms present in the soil, thus having a complete use. In Figure 01 it is possible to observe the combination scheme of the septic tank with the wetlands.

Figure 01 - Combination diagram of septic tanks and wetlands.



Source: Authoress (2024).

According to Tonetti (2018), constructed wetland systems have articulated material inside them as a support for the growth of plants and microorganisms, and in this research, gravel 1 was used as a support. To calculate the volume of gravel 1, the sum of the wetland areas multiplied by the height of 0.10 m was considered, totaling 37.19 m³, considering the market value of gravel 1, thus finalizing the items necessary for the installation of the decentralized sewage system.

For the restorations, only the restoration of grass was considered, since this alternative does not involve intervention in the paving. In this way, the sum of the sections that were excavated in places where there was grass vegetation was calculated, being 749 m multiplied by 0.80 m in width, totaling 599.20 m², at a value of R$ 17.04 per m², generating the total for the item of R$ 10,210.37.

For Alternative II, the BDI of 26.44% was also used, calculated from the total value of R$ 1,093,388.35, generating the value of R$ 289,091.88 in indirect expenses, thus totaling R$ 1,382,480.23 in executive costs for Alternative II.

Maintenance and operation budget

For the alternative of the decentralized sewage system, the costs of hours made available by IFGoiano's own employees were taken into account, which will be directed to the maintenance of the decentralized units. Maintenance included mowing and pruning of plants in the wetlands.

ISSN 2318-8472, v. 12, n. 87, 2024

The monthly availability of hours for mowing and pruning plants was considered. It was considered that the estimated productivity of the service is 50 m²/h, taking into account the execution time and travel (RODRIGUES, et al, 2010). The value of R$ 23.28/h was considered, the cost of a gardener and mower according to SINAPI. Considering the total area of plantations of the UDs is 371.92 m². Therefore, the time available for this employee will be 7.43 hours per month, rounded to 8 h/month. For the period of 240 months, this resulted in a total of R$ 44,697.60 in operation and maintenance costs.

Taking into account the 20-year project period, the cost of implementing the decentralized sewage system was estimated at R$1,427,177.83.

Technical analysis

In the decentralized alternative, it is not generally necessary for the topography to be favorable, but in the route taken, the topography of the terrain has a favorable decline in the direction of the final deposition. It is also possible to observe that the social acceptance of the system by users is not so high because it is still a technique unknown to most users. Since this type of work is carried out together with the campus operation, greater attention must be paid to all safety requirements, so that campus visitors do not suffer accidents. Due to the independence of the UDs, the execution can be fractionated, and a planning of stages can be made to reduce inconvenience to campus visitors.

This alternative does not require approval from the service provider, which makes implementation faster. However, there is still a need to carry out a more in-depth study to prepare the executive project. It is important to note that this type of system generates minimal odor and mosquitoes, as the wetland is subsurface, meaning it does not have contact with the atmosphere (ABNT, 1997).

5 CONCLUSION

The alternatives proposed in this research for the solution of the campus sewage system are based on the current technical legislation and are relevant to the current situation of the campus. According to what was explained, it was observed that the ease of execution and less disruption indicate that the best alternative would be the application of collection and final disposal sectorized by the system of septic tanks and constructed wetlands, even if it is not popularly known. It was also observed that from the economic aspects, alternative II would be more viable, taking into account that the execution value was R$ 1,382,480.23, compared to the centralized system of alternative I which was R$ 1,849,549.35, bringing considerable savings. In addition, the implementation and operation of the centralized system over a 20-year period resulted in an estimated cost of R$ 13,187,424.57 and the cost of the decentralized system is considered insignificant compared to the estimated cost of the centralized system, as the existing campus employees themselves will perform the service that involves operation and maintenance.

ISSN 2318-8472, v. 12, n. 87, 2024

6 ACKNOWLEDGMENTS

Thanks to the Federal Institute of Education, Science and Technology Goiano, Rio Verde Campus, for the support/assistance in the publication of this work.

7 REFERENCES

AMAE. **RESOLUÇÃO NORMATIVA Nº 08/2021.** Regulamenta as condições gerais para prestação dos serviços públicos de abastecimento de água e esgotamento sanitário no município de Rio Verde – Goiás. Rio Verde: AMAE, 2021. Disponível em: le. Acesso em: 23 out. 2023.

ASSOCIAÇÃO BRASILEIRA DE NORMAS TÉCNICAS**. ABNT NBR 7229**: projeto, construção e operação de sistemas de tanques sépticos - procedimento. Rio de Janeiro: ABNT, 1993.

ASSOCIAÇÃO BRASILEIRA DE NORMAS TÉCNICAS. **ABNT NBR 13969**: tanques sépticos – Unidades de tratamento complementar e disposição final dos efluentes líquidos – projeto, construção e operação. Rio de Janeiro: ABNT, 1997.

FUNAAASSOCIAÇÃO BRASILEIRA DE NORMAS TÉCNICAS**. ABNT NBR 17015**: Execução de obras lineares para transporte de água bruta e tratada, esgoto sanitário e drenagem urbana, utilizando tubos rígidos, semirrígidos e flexíveis. Rio de Janeiro: ABNT, 2023.

BRASIL. **DNER-ES 344/97 – Edificações – serviços preliminares.** Rio de Janeiro: DNER, 1997.

BRASIL. **Lei nº 14.026, de 15 de julho 2020**. Atualiza o marco legal do saneamento básico, [2020b]. Disponível em: https://www.planalto.gov.br/ccivil_03/_ato2007-2010/2007/lei/L11445compilado.htm. Acesso em: 29 abr. 2023.

BRASIL. Ministério da Educação. Instituto Federal Goiano. **Conheça o Instituto Federal Goiano – Campus Rio Verde.** [2017b]. Disponível em: https://www.ifgoiano.edu.br/home/index.php/ultimas-noticias-rio-verde/5178-conheca-o-instituto-federal-goiano-campus-rio-verde. Acesso em: 23 out. 2023.

BRASIL. Ministério da Educação. Instituto Federal Goiano. **54 anos do Campus Rio Verde do Instituto Federal Goiano.** [2021b]. Disponível em: https://www.ifgoiano.edu.br/home/index.php/ultimas-noticias-rio-verde/17550-54-anos-do-campus-rio-verde-do-instituto-federal-goiano.html. Acesso em: 23 out. 2023.

BRASIL. Ministério do Trabalho e Emprego. **NR 18 – Segurança e saúde no trabalho na indústria da construção civil.** (2022a). Redação da Portaria MTb, de 08-06-1978, e alterações posteriores até Portaria MTP de 29-12-2022.

BRASIL. Ministério do Trabalho e Emprego. **NR 24 – Condições sanitárias e de conforto nos locais de trabalho.** (2022b). Redação da Portaria MTb, de 08-06-1978, e alterações posteriores até Portaria MTP de 05-09-2022.

BRK. **Tratamento de esgoto no brasil ainda está longe do ideal.** [2019]. Disponível em: https://blog.brkambiental.com.br/tratamento-de-esgoto-no-brasil/#:~:text=O%20Plano%20Nacional%20de%20Saneamento%20B%C3%A1sico%20(Plansab)%20definiu%20a%20universaliza%C3%A7%C3%A3o,menos%2088%25%20do%20territ%C3%B3rio%20nacional. Acesso em: 30 abr. 2023.

CLIMATE DATA. **Clima Rio Verde Goiás Brasil.** Disponível em: < https://pt.climate-data.org/america-do-sul/brasil/goias/rio-verde-4473/>, acesso em: 02 dez. 2023.

SINAPI. **Custos e composições analíticos** – encargos sociais desonerados. Goiânia: CAIXA, 2023.

TCU. **Acórdão 2622/2013** – Plenário: Conclusão dos estudos desenvolvidos pelo grupo de trabalho interdisciplinar constituído por determinação do acórdão n.2369/2011 – plenário para adoção de valores referenciais de taxas de benefício e despesas indiretas para diferentes tipos de obras e serviços de engenharia e para itens específicos para aquisição de produtos. Brasília: TCU, 2013.

GC Revista Nacional de Gerenciamento de Cidades
National Journal of City Management

ISSN 2318-8472, v. 12, n. 87, 2024

TONETTI, A. L. et al. **Tratamento De Esgotos Domésticos Em Comunidades Isoladas**. Campinas: Biblioteca Unicamp, 2018.

TSUTIYA, M. **Abastecimento de água**. 3. Ed. São Paulo: USP, 2006.

TSUTIYA, M. T.; SOBRINHO, P. A. **Coleta e Transporte de Esgoto Sanitário**. 3. Ed. Rio de Janeiro: Abes, 2011.