Risk flood matrix for urban services in Baghdad city

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Abstract. The hazards of floods in the world were and still vague matters to forecast because it is difficult to predict the type of flood that the city will be exposed to and the amount of damage it will cause if it happens to a city, However, it is very important to understand the level of risk for each case of expected floods (whether the flooding is pluvial flood or dam failure flood), That’s make residents and decision-makers understand how to deal with obscure areas and how to choose land uses and locate them in the appropriate place away from risks and according to urban planning standards, The risk matrix is a new method for planning institutions to study and understand the lands and avoid locating land uses in dangerous lands because it is considered an important tactic in the strategic plans that must be carried out for the lands before embarking on the establishment of projects and urban infrastructure services, The risk matrix includes an inventory of the expected risks that these lands may pass through on the one hand and the type of uses on the other hand, to study the potential of exposure of these lands and uses to the expected risk, This paper discusses the impact of the hypothetical collapse of the Mosul Dam on some of the infrastructure urban services of the city of Baghdad, for example (main water plants, main power stations, sewage treatment plants, oil refinery, Baghdad International Airport) and in two cases (collapse in the case of the level of the lake of the dam 319 m and The collapse in the case of the level of the lake of the dam 335 m), The result is two risk matrices that show three risk levels for each service (low risk, medium risk, high risk) and for two cases of dam lake level.

1. Study Area

1.1. Baghdad

The location of Baghdad capital of Iraq is between 44° 21′ E, 33° 28′ N and 44° 22′ E, 33° 11′N (figure 1) in the middle of Iraq ,In 1973, Paul Surfs’ comprehensive development plan was revised to revitalize Karkh and Rusafa as the central area of the capital figure (2), Baghdad has (9) municipalities with a population of 8 million.

The Tigris River flows through Baghdad. The population has begun to settle along the river bank. With the rapid spread of river to larger areas, Tigris River serves the city in many ways, especially in meeting the huge water needs of 24% of the country’s population and residents living in Baghdad and its suburbs.
Figure 1. Baghdad location
Sources: Researcher, depended on Iraqi Ministry of planning data

Figure 2. Baghdad Land use
Source: The comprehensive development plan for the city of Baghdad
1.2 Mosul Dam

Mosul Dam is the largest dam in Iraq and one of the four largest in the Middle East. Built in the eighties of the last century to prevent flooding downstream, generate electricity and support the agricultural sector through irrigation. The city of Baghdad has reduced its dependence on energy provided by the Mosul Dam; it regulates the flow of the Tigris River upstream, figure (3). There is no doubt that Baghdad has benefited from it and avoided frequent seasonal flooding.

The dam is constructed above ground with geological formation materials that have high solubility in water (gypsum, anhydrite and lime sand). Since the construction of the dam began in 1985, its water volume has been approximately 11 billion cubic meters. Problems and close the gap. This requires permanent monitoring and continuous maintenance of the dam foundation (injection of cement and nabutite).

The dam break is only effective as a flood if there is no destructive building collapse.

Lately, Iraq has suffered special circumstances and abnormal conditions. Such as wars, insecurity, weakness and lack of experience or Moreover, the lack of materials and equipment required for maintenance, and the lack of budget, all these combined factors seriously affect the regular maintenance work. This threatens the stability of the dam and its structural integrity. And it is hard to maintain the necessary maintenance schedule, which exacerbates the risk of a dam collapse.

The government is aware of the seriousness of the problem and the huge consequences of the dam failure, which affects millions of people along the Tigris River. Including Baghdad city.

Therefore, in 2016, the Iraqi government brought in an international company (Trevi) with technical expertise. Repair, maintain, upgrade and upgrade the dam structure, equipment, monitoring system, knowledge transfer, and establish local expertise and capabilities to maintain the dam. It is expected that the intervention of international technical expertise will make a positive contribution to improving the durability of the dam and reducing the hazard of a dam collapse.

The collapse of the Mosul dam has a destructive effect in the form of high tsunami waves (ranging from 4 meters to 55 meters), which is destructive and removes any obstructions. The intensity of the waves, the height of the waves and the amount of water gradually decrease downstream. In Baghdad, about 450 km. from the dam, the waves may weaken. This is because the earth is naturally flat. However, the spread will be greater and will cover most of Baghdad.

The important point is that we must concentrate on studying the foundations of the submerged buildings in the city for different purposes and the extent of flooding.
2. Urban services in the city of Baghdad:
Since Baghdad city was built, it includes vital institutions that may be the first of its kind in the Middle East, and at the present time, Baghdad contains ancillary urban services such as oil refineries, electricity, water and sewage stations, the international airport ... etc., as shown in figure (4).

Figure 4. Locations of Anchor Urban Services in Baghdad
Source: the researcher based on Arc map images

We notice that these services are distributed between the city center and its suburbs, and each use is according to the planning standards of the city.
For example, the airport located in the suburbs is a correct procedure in terms of location, being far from the residential zone, to avoid noise pollution from aircraft noise and potential accidents.
The main water plant is located near the river for easy access to water sources.
And the location of the sewage plant is outside the city and near the river to return treated water to the river, and so on.

3. Matrix construction
When studying the hypothetical scenario of the collapse of the Mosul Dam, which was prepared by the Ministry of Water Resources in 2014, which affects the city of Baghdad by flooding only and not destruction, because the city of Baghdad is located 450 km south of the dam and the fact that Baghdad is almost flat, so the scenario of the sinking of the city of Baghdad in the event of the collapse of the dam, as shown in the two figures (5, 6).
Figure 5. Hypothetical Mosul dam failure model in Baghdad, Where the maximum water depth in lake is 319 m
Source: Researcher depended on Iraqi Ministry of water resources data

Figure 6. Hypothetical Mosul dam failure model in Baghdad, Where the maximum water depth in lake is 335 m
Source: Researcher depended on Iraqi Ministry of water resources data

4. The urban services risk matrix in case height of the dam lake 319 m:
When the digital layers of both the collapse and flooding scenarios are matched with urban service sites and for the scenario (lake height 319 m), the following maps are produced:
1- Dora oil refinery (Fig. 7) and Baghdad International Airport (Fig. 8) in case that the level of the dam lake is 319 m

Figure 7. Dora oil refinery inundation
Source: Researcher

Figure 8. Baghdad International Airport inundation
Source: Researcher

2- Power plants figure (9), figure (10) and figure (11) in case of dam lake water level is 319:
Figure 9. South Baghdad power plant inundation
Source: Researcher

Figure 10. Second South Baghdad Power plant inundation
Source: Researcher
3- Water plants figure (12), figure (13) and figure (14) in case of dam lake water level is 319m:

Figure 11. Rustumya power plant inundation
Source: Researcher

Figure 12. East Tigris water plant inundation
Source: Researcher
Figure 13. Alwehdah water plant inundation  
Source: Researcher

Figure 14. South Baghdad water plant inundation  
Source: Researcher
4- Sewage water plants, figure (15) and figure (16) in case of dam lake water level is 319m:

![Figure 15. Rustumya sewage water plant inundation](source)

Source: Researcher

![Figure 16. Saydya sewage water plant](source)

Source: Researcher

Then the bellow table illustrate type of service and inundation water level in case of water lake level is 319:
Table 1. Type of service and inundation water level in case of water lake level is 319:

| Service                      | Ratio of inundation | Level of Inundation (m) |
|------------------------------|---------------------|-------------------------|
| Dora oil refinery            | Total               | 1.5 – 2.8               |
| Baghdad Airport              | Partial             | 0 - 3.7                 |
| South Baghdad Power plant    | Total               | 1.8 – 13                |
| Second South Baghdad Power   | Total               | 2.4                     |
| Rustumya Power plant         | Partial             | 0.3                     |
| East Tigris Water plant      | Total               | 1.8 – 14                |
| Al wehda water plant         | Total               | 0.8 – 4                 |
| South Baghdad water plant    | Total               | 1                       |
| Rustumya sewage plant        | None                | 0                       |
| Syadaya sewage plant         | Total               | 1.2                     |

By given class for every value of inundation level

Table 2. Classes of inundation

| Inundation level | Class            |
|------------------|------------------|
| 0                | Non inundation   |
| 0.1-2.5          | Small inundation |
| 2.6-5            | Medium inundation|
| 5.1-14           | High inundation  |
The Risk matrix of urban services in Baghdad city in case of dam lake water level is 319m is:

| Service Type                               | Non inundation (Non Risk) | Small inundation (Small Risk) | Medium inundation (Medium Risk) | High inundation (High Risk) |
|--------------------------------------------|---------------------------|-------------------------------|---------------------------------|-----------------------------|
| Dora oil refinery                          |                           |                               |                                 |                             |
| Baghdad Airport                            | √                          |                               |                                 |                             |
| South Baghdad Power plant                   |                           |                               |                                 | √                           |
| Second South Baghdad Power plant            |                           |                               | √                                |                             |
| Rustumya Power plant                       |                           |                               |                                 | √                           |
| East Tigris Water plant                    |                           |                               |                                 |                             |
| Alwehda water plant Tigris                 |                           |                               |                                 |                             |
| South Baghdad water plant                  |                           |                               |                                 |                             |
| Rustumya sewage plant                      | √                          |                               |                                 |                             |
| Syadya sewage plant                        |                           |                               |                                 |                             |

Matrix (1) urban services in Baghdad city in case of dam lake water level is 319m
Resource: Researcher

5. The urban services risk matrix in case height of the dam lake 335 m:
When the digital layers of both the collapse and flooding scenarios are matched with urban service sites and for the scenario (lake height 335 m), the following maps are produced:
1- Dora oil refinery (Fig.17) and Baghdad International Airport (Fig. 18) in case that the level of the dam lake is 335 m.

![Figure 17. inundation of Dora oil refinery](image-url)
Figure 18. inundation of Baghdad International Airport
Source: Researcher

2- Power plants figure (19), figure (20) and figure (21) in case of dam lake water level is 335:

Figure 19. South Baghdad power plant inundation
Source: Researcher
Figure 20. Second South Baghdad Power plant inundation
Source: Researcher

Figure 21. Rustumya power plant inundation
Source: Researcher
3- Water plants figure (22), figure (23) and figure (24) in case of dam lake water level is 335m:

![Figure 22. East Tigris water plant inundation](image)

*Source: Researcher*

![Figure 23. Alwehdah water plant inundation](image)

*Source: Researcher*
Figure 24. South Baghdad water plant inundation
Source: Researcher

4- Sewage water plants, figures (25) and figure (26) in case of dam lake water level is 335m:

Figure 25. Rustumya sewage water plant inundation
Source: Researcher
Table 3 illustrates type of service and inundation water level in case of water lake level is 335:

**Table 3.** Type of service and inundation water level in case of water lake level is 335:

| Service                      | Ratio of inundation | Level of inundation(m) |
|------------------------------|---------------------|------------------------|
| Dora oil refinery           | Total               | 1.3 – 5                |
| Baghdad Airport             | Total               | 1.5 -3.5               |
| South Baghdad Power plant   | Total               | 2.7-14                 |
| Second South Baghdad Power  | Total               | 2.5                    |
| Power plant                 | Partial             | 1.5                    |
| Rustumya Power plant        | Total               | 2 -14                  |
| East Tigris Water plant     | Total               | 2 -14                  |
| Al wehda water plant        | Total               | 4.6                    |
| South Baghdad water plant   | Total               | 2 - 2.3                |
| Rustumya sewage plant       | Partial             | 0.2                    |
| Syadya sewage plant         | Total               | 2                      |

By given class for every value of inundation level then (table 4) will be:
Table 4. Classes of inundation:

| Inundation level | class         |
|------------------|---------------|
| 0                | Non inundation|
| 0.1-2.5          | Small inundation|
| 2.6-5            | Medium inundation|
| 5.1-14           | High inundation|

The Risk matrix of urban services in Baghdad city in case of dam lake water level is 335m is:

| Service Type     | Non inundation (Non Risk) | Small inundation (Small Risk) | Medium inundation (Medium Risk) | High inundation (High Risk) |
|------------------|---------------------------|-------------------------------|---------------------------------|-----------------------------|
| Dora oil refinery|                           |                               |                                 |                             |
| Baghdad Airport  |                           |                               |                                 |                             |
| South Baghdad    |                           |                               |                                 |                             |
| Power plant      |                           |                               |                                 |                             |
| Second South     |                           |                               |                                 |                             |
| Baghdad Power    |                           |                               |                                 |                             |
| Rustumya Power   |                           |                               |                                 |                             |
| plant            |                           |                               |                                 |                             |
| East Tigris      |                           |                               |                                 |                             |
| Water plant      |                           |                               |                                 |                             |
| Alwehda water    |                           |                               |                                 |                             |
| plant Tigris     |                           |                               |                                 |                             |
| South Baghdad    |                           |                               |                                 |                             |
| water plant      |                           |                               |                                 |                             |
| Rustumya sewage  |                           |                               |                                 |                             |
| plant            |                           |                               |                                 |                             |
| Syadya sewage    |                           |                               |                                 |                             |
| plant            |                           |                               |                                 |                             |

Matrix (2) urban services in Baghdad city in case of dam lake water level is 335m

6. Matrix Analysis
Note from the two matrices above that:
1- In case of level of the dam lake 319 m (matrix No.1) the sewage treatment plant in Rustumiya is not exposed to the risk of being flooded, while (the second gas station south of Baghdad, the Al-Rustumiya power station, the water plant south of Baghdad, and the sewage treatment plant in Al-Saydya) There is a small risk as a result of the low flooding height (0.1 m - 2.5 m). (Dora refinery, Baghdad airport, and the water plant of Al wehdah project) are exposed to moderate risk due to the average height of floods (2.6 m - 5 m). Tigris is in great danger due to high flooding (5.1 - 14 m)
2- In the case of the level of the dam lake 335 m (Matrix No.2) exposed (the second stream plant south of Baghdad, the Al-Rustumiya power station, and the water plant in southern Baghdad. And the water plant of the East Tigris project) is in great danger due to the high flooding height (5.1 - 14 m)
2- In the case of the level of the dam lake 335 m (Table No. 4), (the second gas station in southern Baghdad, the Al-Rustumiya power station, the liquefaction plant in southern Baghdad, the sewage treatment plant in Al-Rustumiya and the sewage treatment plant in Al-Saidiyah) are exposed to little risk due to the high flooding. The level is (0.1 m - 2.5 m) and (Dora refinery, Baghdad airport, and the water plant of the Al wehdah project) are exposed to moderate danger due to the average height of
floods (2.6 m-5 m), and (the gas power plant in southern Baghdad and the water plant of the East Tigris project) are exposed to a great danger Due to the high flooding height (5.1m-14m).

3- Services located on the bank of the Tigris River are more prone to flooding

7. Conclusion
As the result Risk matrix illustrated we can conclude the flowing points:
1. GIS is a good technique that we can locate the urban services and merge it with flood scenario to observe the inundation and dangerous areas.
2. Studying flood risk matrix draw the boundary of risk areas and safe areas to construct urban services, its help the planning team to make the right decision
3. There are some services that were not affected by the flood due to the high ground on which this service is built.
4. The matrix showed that urban services at the river's edge are the most vulnerable to flooding, while services located in the suburbs of the city further from the river have less exposure to flooding. However, there is a need to locate some urban services near the river, such as the water plants and sewage plants, in order to do their job better.

8. Recommendation
1- As important as dams are, it is also important to study the model of their collapse to avoid danger and losses.
2- Study of the risk matrix for pre-existing land uses opens a new approach for reducing the risk to it by strengthening defenses against floods, establishing early warning devices and establishing alternative services for times of crisis.
3- The risk of lands must be studied before embarking on the process of signing urban services by means of a risk matrix that indicates the extent of the risk to which these lands are exposed or will be exposed.
4- Study the risk matrix reveals to the planning team the risk-free lands for new land uses.

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