Seismic Hazard and Total Risk of Existing Large Dams in the Marmara Basin, Turkey

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Abstract

Safety evaluation is a fundamental stage of existing dams and their appurtenant structures, which have a high-risk potential for downstream life and property. Turkey is a country, which seismically settled at one of the most active regions in the world, and earthquakes with high magnitude frequently occur here. There are some regions, which are severely under threatening of earthquakes. One of them is the Marmara region with twenty-four million people. This region, namely the Marmara basin, has at least forty-five large dams with different types. This study considered nineteen of them to relieve their seismic hazard parameters for all dam sites and total risk for each structure. The study area is lying in a seismically, very active part of Turkey. The southern part of the basin is structurally cut by the North Anatolian Fault, which is a famous structural feature that produces deathful earthquakes, and its offshoots. The analyses have indicated that peak acceleration widely ranges for the nineteen dam sites of this basin. The total risk analyses have concluded that most of the dams in the metropolitan area have high-risk classes and a significant effect for public safety.

Index terms— dam, earthquake, seismic hazard, total risk.

1 Introduction

he ratings of seismic hazard of the dam site and the risk potential of the structure are the main factors acting on public safety for downstream life. The peak ground acceleration, derived from the design earthquake that produces the seismic loads, is a mainly used criteria of the seismic hazard of a dam site. The dam height, reservoir capacity, potential downstream damages and evacuation requirements are the (2012) states that risk evaluation utilized the structure characteristics and seismic hazard ratings separately. According to Bureau (2003), the total risk factor for dam structure should depend on together these two factors. Recently, the ICOLD (2016) has published the guideline for selecting seismic parameters for large dams.

Turkey is a country that desires to use land and water resources effectively. The total number of large dams constructed throughout the country is more than 1250. Most of them are of the embankment type. However, the number of concrete and rolled-compacted concrete dams increase recently. The dam design engineers in Turkey think that embankment dams are a suitable type for the sites having high seismic activity, Author: Full Professor, Department of Civil Engineering, Osmangazi when well compacted according to the specifications. However, the author states that strong ground shaking can result in instability of embankments of the earth and rockfills and loss of strength at the foundations, especially for dams that are under near-source effect. Author and co-workers have so many research studies for the structures discussed in the basin and neighboring areas (Tosun and Tosun, 2017a; Tosun, 2018; Tosun and Onder, 2018; Tosun et al. 2020). They also studied on river basin risk analysis and seismic hazard of large dams in Turkey (Tosun and Seyrek, 2010;Tosun, 2011;Seyrek and Tosun, 2011;Tosun, 2012;Seyrek and Tosun, 2013;Tosun, 2015;Tosun and Oguz, 2017;Tosun and Tosun, 2017b).

The study considers existing large dams in the Marmara basin, which covers lands around the Marmara Sea in Turkey (Fig. 1). This basin has a surface area of 2.31 million ha with a water yield resources of 8.3 billion cu.m per year at the Northwest Anatolia. This study deals with an assessment of seismic hazard and total risk, and evaluates 19 large dams, which have a hydraulic height between 10.1 and 109.0 m, in the Marmara basin.

Table 1 shows their technical characteristics. There are twelve large dams in the basin for providing domestic water to the Istanbul Metropolitan area in which seventeen million people are living. However, the existing dams in the Northern part of the basin, which were constructed by the Istanbul Water and Sewerage Administration, were excluded in this study because of being lack of data.

2 Methods of Analysis

Seismic hazard is the main factor acting on the total risk of dam structures. The peak ground acceleration (PGA) is the parameter to be used in defining the seismic hazard of a dam site. For each dam site, author identifies all possible seismic sources and evaluates their potential in detail, as based on the guidelines (Fraser, 2002) and the unified seismic hazard modeling for the Mediterranean region introduced by Jiminez et al ??2001). The extensive surveys and a search of available literature identify several energy sources to analyze the seismic hazard of dams in Turkey. The seismic hazard analyses also depend on the data instrumentally recorded earthquakes that occurred within the last 100 years. As summary, the study considers seismic zones and earthquakes within the area having a radius of 100 km around the dam site.

The seismic hazard study includes probabilistic and deterministic analyses. For dam sites, design engineers generally use the deterministic and probabilistic seismic hazard analyses. The deterministic seismic hazard analysis (DSHA) considers a scenario having a four-step process and provides a straightforward framework for the assessment of the worst ground motions. The probabilistic seismic hazard analysis (PSHA) defines a framework for uncertainties to identify and combine in a rational manner. DSHA takes into account geology and seismic history to identify earthquake sources and to interpret the strongest earthquake with regardless of time. In comparison, the PSHA considers uncertainties in size, location and recurrence rate of earthquakes (Kramer, 1996;Krinitzsky, 2005).

The study adopted various attenuation relationships to calculate the peak ground acceleration (PGA) acting on dam sites due to unavailability of strong motion records. This study primarily taken into account eight separate predictive relationships for horizontal peak ground acceleration (Campbell, 1981

3 Seismic Hazard Analyses

The analyses of seismic hazard in this context consider all possible seismic sources for dam sites in the Marmara basin based on the zonation map of Turkey, prepared by The National Disaster Organization and other Institutes for general use. The author and his co-workers modified it to use for dam projects. They considered seismic history and local geological features to quantify the rate of seismic activity in the basin. The detailed evaluation indicated that there are twoseparated seismic zones in the related area.

In Turkey, The National Geological Survey released a new seismo-tectonic map to the public in 2013 (MTA, 2013). Fig. 1also shows the study area on the national seismo-tectonics model. The ICOLD (2016) defined the near-field motion, which is ground motion recorded in the vicinity of a fault. This specification suggested a correlation between the radius of near field area and earthquake magnitude based on the cases in West United States. The author established limits of near-field motion for the investigation area. According to this model, there are eight dams, which are under the near-field motion. The model indicated that earthquakes having a magnitude (Mw) between 5.6 and 7.5 can be possible and the minimal distance to the fault segment can range between 1.7 and 121.1 km in the basin. Five existing dams considered in this study are under nearfield motion (Table 2).

The deterministic analyses indicate that peak ground acceleration (PGA) changes within an acceptable range when excluded five dams, which are under the near-field motion. The PGA values range from 0.036g to 0.394g for the 50th percentile and from 0.061g to 0.650g for the 84th percentile, respectively (Table 2). The PGA data are very high for the Yenice-Gonen, Buyuk-Cekmece and Sazl?dere dams, the PGA values are also at a considerable level even if they are not under near-field motion.

The probabilistic hazard analyses introduce PGA values within a wide range. For MDE, those are between 0.120g and 0.630g, while the same values range from 0.102g to 0.509g for OBE. The PGA data for OBE and MDE are high for the dams, which are under near-field motion, mentioned above for deterministic analyses. It is an impressive result that maximum PGA values for OBE, MDE, and SEE belong to the Gokce dam even if its energy source produces a moderate magnitude earthquake (5.9 in Mw).The author thinks that it probably depends on earthquake intensity. The probabilistic hazard analyses also give critical values for Cokal, Kirazdere, Tasoluk, and Yenice dams as given in deterministic hazard analyses.

4 Total Risk Analyses

Throughout this study, the total risk analyses of the basin considered the national specification (DSI, 2012). in which total risk factor depends on reservoir capacity, height, evacuation requirement, and potential hazard, and the Bureau method, which considers dam characteristics, evacuation requirements and downstream damage potential. The national specification adopted the ICOLD (1989) guidelines. The Bureau method recommends four separate risk classes ranging from I (low risk) to IV (extreme risk) as based on the Total Risk Factor (TRF).

Table 3 summaries the total risk analyses of the dams considered in the study. Five dams (Cokal, Gokce, Kirazdere, Tasoluk, and Yenice-Gonen) classified into extremely high hazard ratios with class IV.In comparison, four dams (Alibey, Buyuk-Cekmece, Elmali-II and Sazlidere) have high hazard rating with hazard class of III. Others are identified in classes of I and II (low to moderate hazard rating). The ICOLD (1989) specification classified dams into hazard class IV with hazard rating of extreme, if the PGA value is greater than 0.25g and the energy source is closer than 10 km from the dam site. According to this statement, five dams mentioned above are classified as hazard class IV with a hazard rating of extreme. Throughout study, most dams, classified into hazard classes of III and IV, have a function to provide domestic water for the metropolitan areas.

For nine dams classified into hazard classes of III and IV, the distance from the dam site to active faults, given on updated seismic maps, ranges from 1.7 km to 27.3 km. The large dams of basins, which are under the influence of the near-field motion, have been constructed to very close to the North Anatolian Fault Zone or its offsets passing through from south of the investigation area. According to DSI Guidelines, all dams with the exception of one structure (Tayfur dam) are categorized into III and IV risk classes with a high and very extremely high-risk rating. Following the Bureau's method, five large dams are classified in risk class III, high-risk rating, while others are in the moderate risk ratio with class of II. The total risk analyses indicate that the solutions obtained from the Bureau method are more rational than those estimated by the DSI guidelines. The TRF values range from 67.10 to 223.3 according to the Bureau method. There are five dams of a risk class of II and fourteen dams of a risk class of III, while there is no dam having a risk class of I in the basin. In other words, seventy-four percent of total dams are identified as a risk class of III with high risk ratio, while the rest are being in class of II with moderate risk ratio.

V.

5 Discussions

There are so many small and large dams in the Marmara basin, Turkey. Some of them, namely Alibey, Buyuk-Cekmece, Cokal, Elmali-II, Gokce, Kirazdere, Sazlidere, Tasoluk, and Yenice-Gonen, has mainly been built for providing domestic water and located in the metropolitan area. These dams have been discussed in more detail in the papers submitted in the local symposiums held in Turkey (Tosun and Onder, 2018 and Tosun, 2019b). The dams, categorized into hazard class of III and IV with high to extremely high hazard ratio and into the total risk of III with high-risk ratio, can cause very serious conditions for downstream life and property when they fail. The author evaluates their earthquake safety and total risk in more detail as given below.

Alibey Dam, located on Alibey river in the Marmara basin, is an embankment dam 28.0-m high with a total embankment volume of 1 927 000 m3. The facility will impound 65.0 hm3 of water with a reservoir surface area of 4.75 km2 at the maximum water level. It provides domestic water with an annual capacity of 33.0 hm3. The side slopes of the main embankment are 2.0H:1V for both upstream and downstream (H=horizontal and V=vertical)). In the section, there are a central impervious zone, which is composed of impervious clay, and a transition section of granular materials to protect the central impervious clay. The shell fill in downstream and upstream parts is composed of semi-pervious clayey material. The geotechnical engineers designed vertical sand drains to provide quick-consolidation of the clayey layer of soft alluvium on the river bed. The analyses indicate that this dam is one of the more critical structure within the Istanbul Metropolitan Area. According to DSHA, the peak ground acceleration resulted by an earthquake of 7.5 magnitudes is 0.191g. As based on PSHA, the values of peak ground acceleration for OBE and MDE are 0.229g and 0.298g, respectively. It is 25.1 km far away from an active fault given in the new seismo-tectonic map of Turkey adopted in 2013.The dam, identified a risk class of III, hasa TRF value of 223.3. The 37-years old embankment is in excellent condition. However, the author recommends its seismic upgrade soon.

Buyuk-Cekmece dam is an earthfill dam located in the Istanbul Metropolitan Area. It has only a 10.1 m height from the river bed, however, its total storage capacity is relatively high. When the reservoir is at maximum capacity, the facility impounds 172.5 hm3 of water with a reservoir surface area of 28.58 km2. It provides domestic water with an annual capacity of 82 hm3 for the European part of the Istanbul metropolitan area. The crest length is 2 476 m, and the side slopes of main embankment are3.0H:1V for both upstream and downstream side (H=horizontal and V=vertical). In the section, there are a central impervious core, which is composed of compacted impervious clay, and a transition section of sandy and gravelly aggregates between the core clay and semi-pervious soils. The alluvium on the river bed, which is composed of different sizes of river bed material, was removed before beginning the construction of the main embankment of dam. According to the DSHA, the peak ground acceleration by an earthquake of 7.5 magnitudes is 0.281g. The PSHA indicates that the values of peak ground acceleration for OBE and MDE are 0.286g and 0.393g, respectively. The dam embankment is only 14.8 km far away from an active fault given in the new seismo-tectonic map of Turkey adopted for 2013.The dam, identified as a risk class of III, has a TRF value of150.8. This 31-year old earthfill dam is in excellent condition, but it cannot meet current seismic design standards. Additionally, it is relatively close to the energy source.

Cokal dam, located at the European part of the Marmara basin, was designed as the type of concrete faced rockfill dam (CFRD). It impounds 204.0 hm3 of water at maximum water level and has 81 m height from the foundation and 571 m length on the crest. The dam body is mainly composed of rockfill material. There is a transition section between the face concrete lining and rockfill. The side slopes are 1.4H: 1V for upstream and downstream of dam body (Fig. 2). The impervious section consists of the concrete slab and the plinth structure on the downstream face. The alluvium on the river bed, which is composed of sandy and gravelly clay, was removed before commencing the construction of the dam body. According to the DSHA, the peak ground acceleration resulted by an earthquake of 6.3 magnitudes is 0.327g as based on PSHA, the values of peak ground acceleration for OBE and MDE are 0.509g and 0.639g, respectively. The dam is only 2.7 km far away from the main faulting system, which has a surface rupture of the North-Anatolian Faulting System in the west. The dam, identified as a risk class of III, has a TRF value of 141.1. Intensive investigations showed that the behavior of CFRD's is questionable after the Wenchuan earthquake of 12 May 2008 in China (Tosun, 2015). Cokal dam is one of most critical structures of the Marmara basin. Therefore, it should be re-analyzed using sophisticated programs to describe its dynamic behavior under severe excitation conditions even if it is a young dam. Year 2020 Global Journal of Researches in Engineering ( ) Volume Xx X Issue II V ersion I E © 2020 Global Journals Seismic Hazard and Total Risk of Existing Large Dams in the Marmara Basin, Turkey from an active fault. The PSHA indicates that the values of peak ground acceleration for OBE and MDE are 0.210g and 0.285g, respectively. Its TRF value is 180.2, and it has a risk class of III. The Elmali-II dam, which is the oldest one of the dams considered for this study is in excellent condition. However, it is necessary to have a seismic upgrade for the dam soon.

Gokce dam is an earth-rockfill typed with a total embankment volume of 133 000 m3.The 50-m high dam, located on the Gokce river in Marmara basin, has a function for providing domestic water of Yalova city and its vicinity. The facility approximately will impound 21.71 hm3 of water with a reservoir surface area of 1.3 km2 at the maximum water level. The crest width is 10 m, and the side slopes of main embankment are 3.0H:1V for upstream and 2.0H: 1V for downstream (H=horizontal and V=vertical). In the section, there are a central impervious core, which is composed of compacted clay, and a transition section of sand, gravel and small-sized crushed rock between the core and rockfill materials for the downstream part and a natural filter zone between the core and earthfill material for the upstream. The downstream shells consist of large-sized crushed rocks. The DSHA and PSHA indicate that Gokcedam is one of the most critical dams within the basin. The DSHA indicates that the peak ground acceleration produced an earthquake of 5.9 magnitudes is 0.285g, and its embankment is 3.1 km far away from a secondary active fault given in the updated seismotectonic map of Turkey. According to PSHA, the values of peak ground acceleration for OBE and MDE are 0.583g and 0.709g, respectively. Its TRF value is 124.6, and the 31-years old dam has a risk class of III with high risk ratio.

Kirazdere dam is a rockfill dam on the Kirazdere River within the Kocaeli Metropolitan area. It has a 109.0 m height from river bed. When the reservoir is at maximum capacity, the facility impounds 60.0 hm3 of water in its reservoir. The dam, finished in 1999, has a function to provide domestic water with an annual capacity of 142 hm3. According to the deterministic seismic hazard analyses, the peak ground acceleration produced by an earthquake of 6.7 magnitudes is 0.329g. Its embankment is 5.3 km far away from the main segment of the North Anatolian Fault Zone given in the updated seismo-tectonic map of Turkey. According to PSHA, the values of peak ground acceleration for OBE and MDE are 0.433g and 0.560g, respectively. The Kocaeli Municipality operates it. This 21-year old rockfill embankment is in excellent condition, but it cannot meet current seismic design standards. It will be under nearfield motion during a forthcoming earthquake. Its TRF value is 146.1, and it has a risk class of III with high risk ratio. Its risk increases because of being no alternative water resources in the region.

Sazl?dere dam is a rockfill dam on the Sazl?dere River near Arnavutköy County. It has a 23.0 m height from river bed. When the reservoir is at maximum capacity, the facility impounds 131.50 hm3 of water with a reservoir surface area of 11.77 km2. The dam, finished in 1996, has a function to provide domestic water for the ?stanbul city with an annual capacity of 55.0 hm3. The crest length is 435 m, and the side slopes of the main embankment are 2.25H:1V for upstream and 2.0H: 1V for downstream (H=horizontal and V=vertical). In the section, there are a central impervious core, which is composed of compacted impervious clay, and a transition section of sandy and gravelly aggregates between the core and finely crushed rockfill. According to the DSHA of this study, the peak ground acceleration produced by an earthquake of 7.5 magnitudes is 0.205 g, and its embankment is 23.0 km far away from an active fault given in the updated seismo-tectonic map of Turkey. The PSHA indicates that the values of peak ground acceleration for OBE and MDE are 0.225g and 0.306g, respectively. Its TRF value is 158.4, and it has a risk class of III. This 24-year old rockfill embankment is in excellent condition. Its reservoir is under the influence of the Istanbul Canal Project to be realized in forthcoming years.

The Tasoluk dam, constructed as rockfill type with embankment volume of 1.7 hm3 on the Tasoluk River of the Marmara Basin in Canakkale province, has a 65-m height from the river basin. The facility impounds 79.4 hm3 of water when the reservoir is at maximum capacity. The dam, finished in 2009, has a function to provide irrigation water. The side slopes of main embankment are 2.0H:1V for upstream and downstream (H=horizontal and V=vertical). In the section, there is a central impervious core, which is composed of compacted clay, and a transition section of granular material between the core and fine crush rock zone materials for both sides (Fig. 3). According to the seismic hazard analyses of this study, Tasolukdam is one of the most critical structures of Marmara basin that the peak ground acceleration by an earthquake of 5.6 magnitude using the DSHA is 0.261g. The PSHA indicates that the values of peak ground acceleration for OBE and MDE are 0.460g and 0.582g, respectively. Its TRF value is 116.9, and it has a risk class of III. Dam site is 1.8 km far away from an active fault. The shell is composed of earth and rockfill materials for upstream and downstream, respectively. There is a transition section of sand, gravel, and small-sized crushed rock between the core and shell materials (Fig. 4).The alluvium on the river bed, which is composed of sand, gravel and fine mixtures, was removed before beginning the construction of the main embankment of the dam. The dam axis is very close to the Yenice-Gonen Fault

Zone (YGFZ), which extends from Gonen East in the Northeast to Yenice's Southwest in the southwest. This fault zone caused an earthquake on March 18, 1953, with a magnitude of 7.2. It is only 1.71 km far away from the surface collapse of YGFZ. The seismic hazard analyses indicate that it is one of the critical dams within the basin. The peak ground acceleration produced by an earthquake of 6.6 magnitudes is 0.394 g. It is only1.77 km far away from the active fault. Moreover, its risk is high for downstream life (total risk factor is 214.1 with high-risk ratio).

6 Conclusions

For this study, nineteen large dams, located on different seismic zones of the Marmara basin, were analyzed to estimate their seismic hazards and risk classes based on the actual earthquakes occurred within the basin and structural features of dams. The North Anatolian Fault zones and its secondary segments are the most critical zone for the basin. There are five existing dams under the near-field motion when considered the new seismo-tectonic map of Turkey. The analyses indicate that Cokal, Gokce, Kirazdere, Tasoluk, and Yenice-Gonen dams are the most critical dams of the basin. Additionally, four large dams (Alibey, Buyuk-Cekmece, Elmali-II, and Sazl?dere), possessing the hazard class of III with high hazard ratio, are also critical dams in the Marmara basin. As a result of this study, 47.4 percent of the dams have been identified as the structures in high and extremely high hazard ratios. In comparison, 31.5 percent of dams is in a moderate hazard ratio. The rest are relatively safe structures when we consider public safety. The author points out that local predictive relationships are an appropriate methodology for estimating the seismic parameters to be used in dynamic analyses. The study clarifies another fact that probabilistic seismic hazard analysis introduces relatively higher PGA values for the dams having high earthquake intensity. Development of attenuation relationships between PGA values obtained from probabilistic and deterministic seismic hazard analyses as considering earthquake intensity can be an promising area for forthcoming studies. [1] [2] [3]

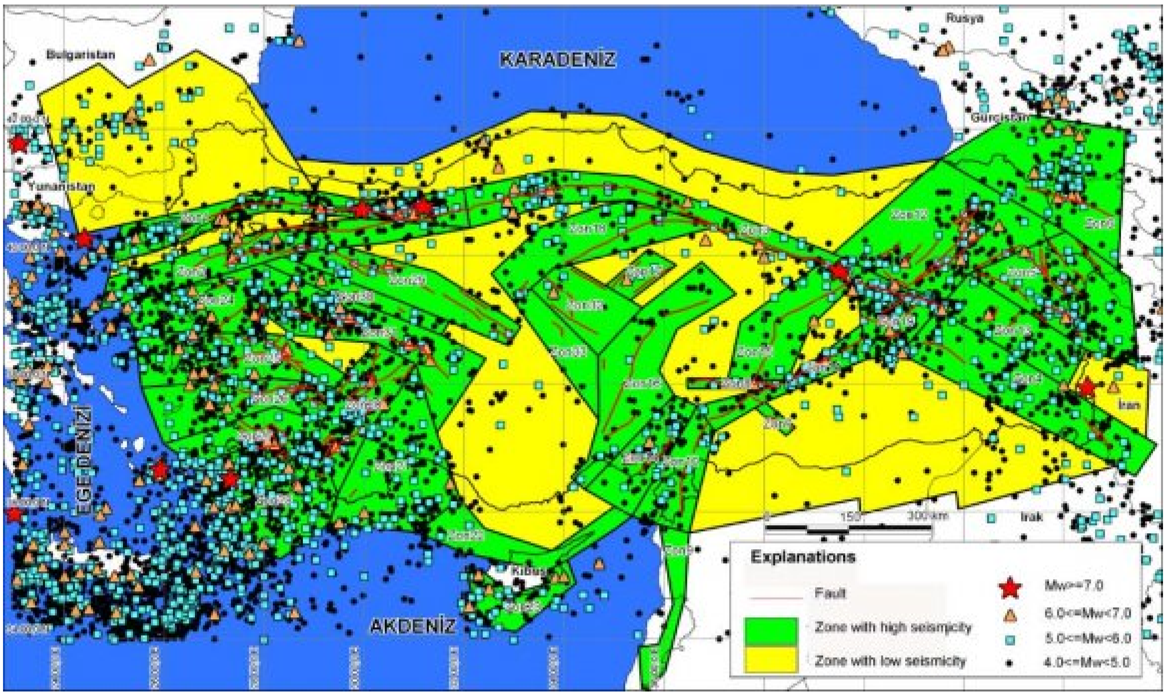


Figure 1:

[1] © 2020 Global Journals

[2] © 2020 Global Journals Seismic Hazard and Total Risk of Existing Large Dams in the Marmara Basin, Turkey

[3] © 2020 Global Journals Seismic Hazard and Total Risk of Existing Dams in the Marmara Basin, Turkey

1

Figure 2: Figure 1 :

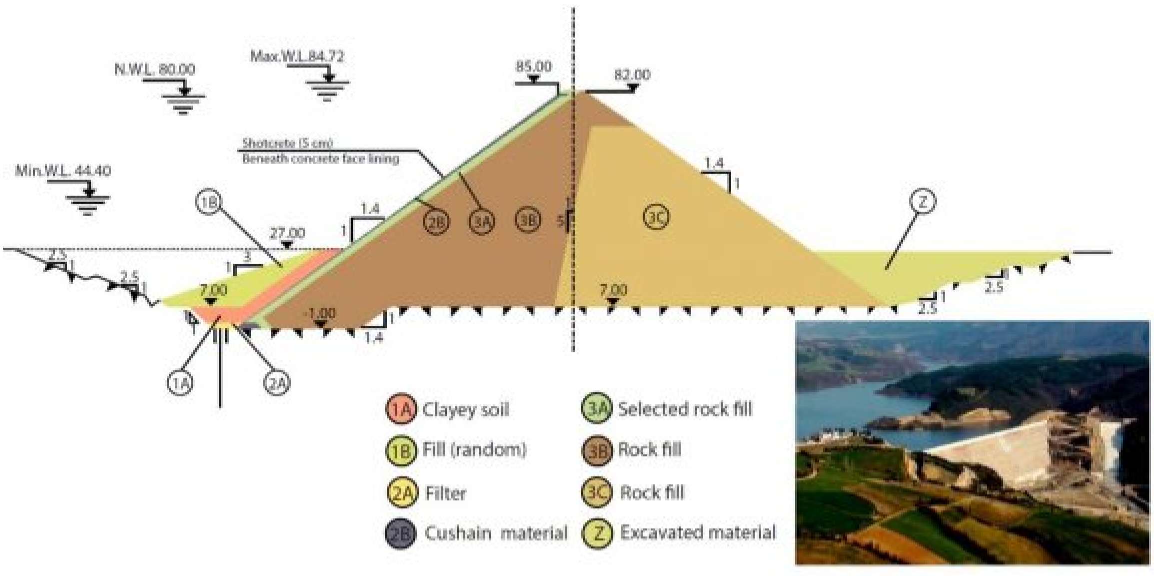


Figure 3:

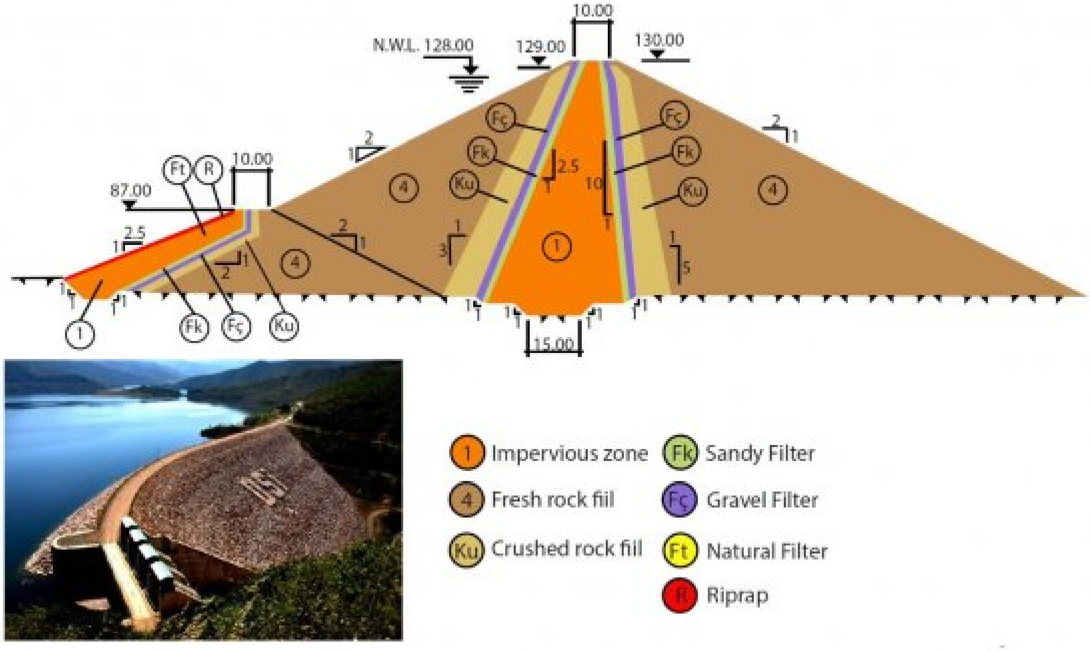
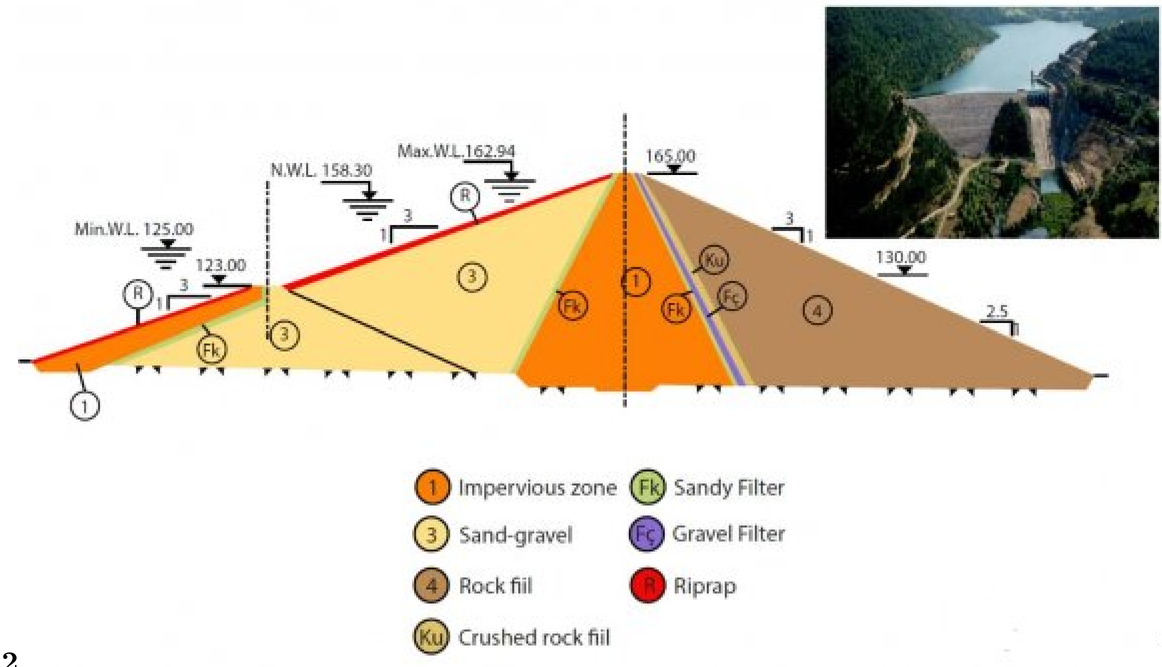


Figure 4:



2

Figure 5: Figure 2 :

1

	Dam	Aim (*)	Height from river bed (m)	Completed Year	Type (**)	Volume of embankment (hm 3)	Volume of reservoir (hm 3)
1	Alibey	D+F	28.0	1983	EF	1.927	65.00
2	Armagan	I	57.5	1999	RF	1.560	51.50
3	Atikhisar	I+D+F	33.7	1973	EF	2.218	52.20
4	Bakacak	I	50.0	1998	RF	2.200	139.00
5	Bayramdere	I+D	56.0	2011	RF	1.000	18.45
6	Buyukçekmece	D	10.1	1987	EF	1.718	172.45
7	Cokal	I+D	57.0	2011	CFR	3.500	204.00
8	Darl?k	D	73.0	1988	RF	1.600	107.00
9	Elmali II	D	42.5	1955	CG	0.103	10.31
10	Gokce	D	50.0	1989	EF+RF	0.133	21.71
11	Gokceada	I+D	33.0	1983	EF	0.560	16.80
12	Kadikoy	I+D+F	34.1	1973	EF	0.680	56.50
13	Kirazl?dere	D	109.0	1999	RF	5.200	60.00
14	Omerli	D	52.0	1972	EF	1.650	436.53
15	Sazlidere	D	23.0	1996	RF	1.780	131.50
16	Tasoluk	I	65.0	2009	RF	1.700	79.40
17	Tayfur	D	39.0	1985	RF	0.298	4.36
18	Umurbey	I	81.0	2003	EF	2.400	24.56
19	YeniceGonen	I+D+E	70.0	1997	RF+EF	2.400	227.04

[Note: (*) D: Domestic Water, E: Energy, F: Flood control, I: Irrigation and IU: Industrial use II.]

Figure 6: Table 1 :

2

			Deterministic Method *					Probabilistic Method **		
#	Dam			Mean PGA 50 (%)	+	Mean PGA 84 (%)	+			SEE in g
1	Alibey	7.5	25.1	0.191		0.313		0.229	0.298	0.413
2	Armagan	6.5	121.1	0.036		0.061		0.102	0.120	0.147
3	Atikhisar	6.5	40.1	0.098		0.163		0.200	0.243	0.300
4	Bakacak	6.6	18.2	0.153		0.255		0.302	0.380	0.492
5	Bayramdere	6.2	26.4	0.091		0.152		0.239	0.293	0.365
6	Buyukçekmece	7.5	14.8	0.281		0.468		0.286	0.393	0.558
7	Cokal	6.3	2.7	0.327		0.540		0.509	0.639	0.825
8	Darl?k	7.7	41.2	0.141		0.230		0.146	0.195	0.268
9	Elmali II	7.5	27.3	0.178		0.292		0.210	0.285	0.394
10	Gokce	5.9	3.1	0.285		0.469		0.583	0.709	0.887
11	Gokceada	6.3	21.9	0.101		0.167		0.264	0.324	0.410
12	Kadikoy	6.3	22.5	0.120		0.198		0.276	0.344	0.441
13	Kirazl?dere	6.7	5.3	0.329		0.544		0.433	0.560	0.747
14	Omerli	7.7	34.6	0.164		0.267		0.178	0.238	0.329
15	Sazlidere	7.5	23.0	0.205		0.335		0.225	0.306	0.428
16	Tasoluk	5.6	1.8	0.261		0.429		0.460	0.582	0.761
17	Tayfur	6.3	18.4	0.130		0.216		0.370	0.451	0.565
18	Umurbey	6.7	42.2	0.083		0.138		0.193	0.238	0.299
19	YeniceGonen IV.	6.6	1.77	0.394		0.650		0.391	0.513	0.702

Figure 7: Table 2 :

3

#	Dam	Hazard Analysis Class	Hazard Ratio	Total Risk (ICOLD,1989) Risk factor	Risk class	Risk ratio	Total Risk (Bureau, 2003) Risk factor	Risk class	Risk ratio
1	Alibey	III	High	30	III	High	223.30	III	High
2	Armagan	I	Low	30	III	High	99.28	II	Moderate
3	Atikhisar	I	Low	24	III	High	143.97	III	High
4	Bakacak	II	Moderate	36	IV	Very high	137.55	III	High
5	Bayramdere	I	Low	26	III	High	83.98	II	Moderate
6	Buyukçekmece	III	High	22	III	High	150.80	III	High
7	Cokal	IV	Extreme	36	IV	Very high	141.14	III	High
8	Darl?k	II	Moderate	32	IV	Very high	160.30	III	High
9	Elmali II	III	High	32	IV	Very high	180.20	III	High
10	Gokce	IV	Extreme	34	IV	Very high	124.55	II	Moderate
11	Gokceada	II	Moderate	24	III	High	136.27	III	High
12	Kadikoy	II	Moderate	24	III	High	143.35	III	High
13	Kirazdere	IV	Extreme	34	IV	Very high	146.09	III	High
14	Omerli	II	Moderate	36	IV	Very high	217.0	III	High
15	Sazlidere	III	High	32	IV	Very high	158.40	III	High
16	Tasoluk	IV	Extreme	34	IV	Very high	116.85	II	Moderate
17	Tayfur	II	Moderate	16	II	Moderate	67.10	II	Moderate
18	Umurbey	I	Low	26	III	High	134.82	III	High
19	YeniceGonen	IV	Extreme	36	IV	Very high	214.06	III	High

Figure 8: Table 3 :

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