FLOOD HYDROLOGY OF THE BINATIONAL COTTONWOOD CREEK/ARROYO ALAMAR, CALIFORNIA AND BAJA CALIFORNIA

PROJECT NUMBER: W-00-5

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NARRATIVE SUMMARY

This report describes the flood hydrology study of Alamar Creek (Arroyo Alamar), located in the city of Tijuana, Baja California. The Alamar Creek is being considered for development by Tijuana's Instituto Municipal de Planeacion (IMPlan). The project entails the river channel improvement from the intersection with the toll road to Tecate (Mexico 2) to its confluence with the Tijuana River, in the city of Tijuana. The length of the channel improvement project is 10 kilometers (km).

The objective of this study was to determine the flood flows associated with return periods of two years to 1,000 years. The analysis has been performed using a generally applicable, deterministic conceptual model of rainfall runoff. In current hydrologic practice, this type of analysis is preferred to that based on parametric or statistical models. The latter require a long period of record, comparable to the predictive horizon (up to 1,000 years), which is not available for Arroyo Alamar.

The methodology for the flood hydrology study of Arroyo Alamar is based on the use of a deterministic-conceptual model for the conversion of precipitation to runoff. It uses either the standard provided by the HEC-1 model of the U.S. Army Corps of Engineers (U.S. Army Corps of Engineers 1990), or its equivalent with a graphical user interphase, the HEC-GeoHMS model (U.S. Army Corps of Engineers 1998). The model used in this study is RAINFLO, developed by Dr. Victor M. Ponce in 1986, which emulates the HEC-1 standard. This model gives comparable results with the HEC-1 model (Lantz 1989) and has been tested in diverse geographical regions, including Baja California (Ponce, et al. 1985; Shetty and Ponce 1997; Ponce, et al. 1999).

The IMPlan, pending consultation with the pertinent technical authorities, should select an appropriate return period for the design of the channelization project. The interpretation of current regulations permits establishes a return period of between 50 years and 200 years for populated agricultural zones, assuming a development of this type. Therefore, in this case the design discharge will not be less than 1,140 cubic meters per second and could be as high as 1,420 cubic meters per second.

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INTRODUCTION

This report describes the flood hydrology study of Alamar Creek (Arroyo Alamar), located in the city of Tijuana, Baja California, Mexico. Alamar Creek is being considered for development by the Instituto Municipal de Planeacion (IMPlan) of the Municipality of Tijuana. The project entails river channel improvement from the intersection with the toll road to Tecate (Mexico 2) to its confluence with the Tijuana River in the city of Tijuana. The length of the channel improvement project is 10 kilometers (km).

The watershed of Alamar Creek is part of the Tijuana River basin, which flows into to the Pacific Ocean at Imperial Beach in San Diego County, California. The Tijuana River basin encompasses San Diego County and the municipalities of Tijuana, Rosarito, and Tecate in Baja California. It is effectively a binational watershed, with the major portion (70%) in Baja California and the remainder in California (Comisíon Nacional del Agua 1994). Therefore, the flood hydrology study comprises the analysis of geographical, geological, climatological, and hydrological data on both sides of the border.

The Alamar Creek watershed is part of the Cottonwood Creek-Alamar Creek-Tijuana River basin system. It is comprised within 32° 30’ and 32° 56’ North latitude and 116° 18’ and 116° 57’ West longitude, with the major portion (86.2%) in California, and the remainder (13.8%) in Baja California. The flood hydrology study comprises the analysis of Cottonwood Creek (the main stream) and its major tributaries: Kitchen, La Posta, Morena, Pine Valley, Potrero, and Campo-Tecate, among others. Cottonwood Creek takes the name Tijuana River at its confluence with Tecate Creek inside California, and later its name changes to Arroyo Alamar as it enters Mexico. Downstream, in the city of Tijuana proper, Arroyo Alamar joins with the Tijuana River, which then crosses the border and flows into the ocean at Imperial Beach.

This study focuses on the flood hydrology of Cottonwood Creek-Arroyo Alamar. The objective is to determine the flood flows associated with return periods of two years to 1,000 years. The analysis has been performed using a deterministic-conceptual model of rainfall runoff of general applicability. In current hydrologic practice, this type of analysis is preferred to that based on parametric or statistical models. The latter require a long period of record, comparable to the predictive horizon (up to 1000 years), which is not available for Alamar Creek.

Background

The Comisíon Nacional del Agua, through its Baja California state office's Water Administration Section, has performed the study entitled "Alamar Creek Watershed, Tijuana, B.C., Hydrology Study" (1993). The objective of this study is to analyze the hydrologic conditions of the Alamar Creek watershed, determine flood frequency, and calculate the flood discharge of the "free basin." The "free basin" is the downstream portion of the basin, which is not subject to regulation by Morena and Barrett Dams, located within the United States and out of the control of Mexico.

The cited study used data for the 14-year period from 1979 to 1992 in the gaging station located on Arroyo Alamar. This was for the purpose of determining the design discharge to use in the delineation of the federal zone.

The study used the following statistical methods: Gumbel, Gumbel two populations (II), and normal distribution. The calculated design discharges for return periods from five years to 10,000 years are shown for reference on lines 1 through 3 of Table 1. The analysis concluded that the normal distribution was more representative of the gaged data, and its values were adopted for design.

The cited study also considers the design discharge, which is 1,720 cubic meters per second (m^3/s), used for the existing channelization in Arroyo Alamar immediately upstream of its confluence with the Tijuana River. This channelization is a trapezoidal section of lined concrete with a length of 1.8km. It was constructed as part of the first phase of the channelization of the Tijuana River, completed in 1970. The study mentions that the emergency spillway of Barrett Dam, located upstream of Alamar Creek, entirely within the United States, is designed for a discharge of 1,698.6m^3/s.

For the delineation of the federal zone, the cited study (Comisíon Nacional del Agua 1993) calculates a design discharge of 801.21m^3/s, which is comprised of two parts:

- The 551 m^3/s discharge pertaining to a 50-year storm for the free basin (according to the normal distribution), i.e., the flood runoff generated exclusively downstream of Barrett Dam
- The discharge of 250.21m^3/s corresponding to the spilling of Barrett Dam

The ratio of discharges (551.0m^3/s to 801.21m^3/s) was calculated from the ratio of drainage areas, taken as 75,864 hectares (ha) for the free basin and 110,314ha for the whole basin. The difference between these two values is 34,450ha, which corresponds to the tributary area of Barrett Dam, excluding that of Morena Dam. The study cited mentions that the discharge to use for the delineation of the federal zone is either the one calculated (801.21m^3/s) or the capacity of the natural channel, whichever is greater.

A similar study was commissioned by the Regional Technical Section of the Regional Directorate of the Peninsula of Baja California at the Comisíon Nacional del Agua the following year (Comisíon Nacional del Agua 1994). This study used gaged measurements for the 15-year period from 1979 to 1993, and this time concluded that the Gumbel II method was the most representative one of the data measured, with the results shown in line four of Table 1. According to regulations established by the National Water Commission, the cited study determined that the discharge to be used in the delineation of the federal zone of Alamar Creek will have a return period of 10 years. This corresponds to a design discharge of $548m^3/s$, i.e., $550m^3/s$.

The difference between these two studies, for the same purposes, is marked. The first study assumes the normal distribution as valid, a return period of 50 years, and considers that a fraction of the total discharge, calculated by means of a ratio of tributary areas, is spilled from Barrett Dam. The second study considers the Gumbel II distribution as valid, a return period of 10 years, and does not consider the spilling of Barrett Dam. It should be mentioned that the federal regulation for the delineation of federal zones establishes a return period of five years in semiarid to humid regions, or greater than or equal to 10 years in arid regions with occasional runoff (ephemeral streams). This last value is applicable to the basin of Alamar Creek.

Description of the Basin

Alamar Creek originates in the United States with the name of Cottonwood Creek, with its headwaters near Elev. 1,646 meters (m) in the vicinity of Crouch Valley, southwest of Mount Laguna, in eastern San Diego County. Cottonwood Creek flows to the South toward Mexico, and it is joined by several tributaries, among them, from upstream to downstream: Kitchen, La Posta, Morena, Hauser, Pine Valley, Corral Canyon, Wilson, Rattlesnake Canyon, McAlmond Canyon, Potrero, Bee Canyon, Campo-Tecate, and Mine Canyon.

Morena and Barrett Dams, located in Cottonwood Creek, form part of the system of reservoirs of the City of San Diego. Morena Dam is located downstream of the confluence of Cottonwood Creek with Morena Creek and upstream of Hauser Creek. Barrett Dam is located downstream of Pine Valley Creek, Corral Canyon and Wilson Creek, and upstream of Rattlesnake Canyon.

Morena Dam is geographically located at 32^o 41' North latitude and 116^o 32' 55" West longitude. The height of the dam, measured above the streambed, is 52.12m, and the length and width of the crest is 167.64m and 6.096m, respectively. The emergency spillway is of *ogee* type without control, with a length of 95.098m and a capacity of $707.92m^3/s$ at the dam crest elevation. Morena Dam was put into operation in 1912. The emergency spillway operated in the years 1916, 1917, 1927, 1928, 1939-44, and 1980-84.

Barrett Dam is located at 32^o 40' 45" North latitude and 116^o 40' 20" West longitude. The height of the dam, measured above the streambed, is 52.12m. The length and width of the crest is 227.381m and 4.572m, respectively. The emergency spillway is of *ogee* type, controlled by 26 floodgates. Each floodgate is 2.438m in height and 3.941m wide, with a total length of 102.467m. The capacity of the emergency spillway is $2491.88m^3/s$ at the level of the 2.438m vertical wall on top of the dam crest. The dam was put into operation in 1922. The spillway operated in the years 1927, 1937, 1938, 1939, 1941-43, 1979-84, 1993, 1994, 1995, and 1998. (The data for Morena and Barrett

Dams was provided by the City of San Diego's Water Department, and converted to metric units for the purpose of this study).

The City of San Diego operates Morena and Barrett Dams mainly for water supply purposes. Therefore, the objective is to retain the greatest possible quantity of water. The operation of these reservoirs for flood control purposes is not well defined, although apparently, it is effective. Partly for this purpose, Barrett Dam is operated with the gates open during the rainy season (November 1 to April 1).

The data on monthly levels for Morena and Barrett Dams was analyzed to determine the mean monthly level [MML] for each month of the year, from which the MMLmean and the MMLmax were obtained. The water levels of Morena Dam (see *Data Management* section) corresponding to the period from 1912 to 2000 show a mean mean monthly level (MMLmean) of 120.09 feet (ft) and a maximum mean monthly level (MMLmax) of 122.50ft. These levels can be compared with the crest level, which is 157ft. The difference between the crest level and the MMLmean (36.91ft, or 11.25m) indicates that Morena Dam is operated well below the crest of the overflow spillway. The difference between MMLmax and MMLmean (2.41ft, or 0.734 m) indicates that Morena dam is operated with very little seasonal variation.

The water levels of Barrett Dam (see *Data Management* section) corresponding to the period from 1921 to 2000 show an MMLmean of 115.42ft and an MMLmax of 121.60ft. These levels can be compared with the crest level, which is 160.9ft. The difference between the crest level and MMLmean (45.48ft, or 13.86m) indicates that Barrett Dam is operated well below the crest of the overflow spillway. The difference between MMLmax and MMLmean (6.18ft, or 1.883m) indicates that Barrett Dam is operated with very little seasonal variation. This analysis supports the conclusion that the operating levels of Morena and Barrett Dams are more dependent on multiannual than annual hydrologic tendencies (or, meteorological droughts as opposed to season variations).

Cottonwood Creek flows downstream of Lake Barrett in a southwestern direction toward Mexico, receiving the contributions of the tributaries Rattlesnake, McAlmond, Potrero, Bee Canyon, Campo-Tecate, and Mine Canyon. After receiving the waters of Tecate Creek, within U.S. territory, the Cottonwood Creek name changes to Tijuana River. However, as this river enters Mexican territory, its name again changes to Arroyo Alamar, which flows in a western direction toward the city of Tijuana, joining the Tijuana River after approximately 16km.

The contributing watershed of Arroyo Alamar, in its confluence with the Tijuana River, is 1,387 square kilometers (km^2) (see *Data Management* section). Of this area, 1,196km^2 (86.2%) is in California and 191km^2 (13.8%) in Baja California.

RESEARCH METHODOLOGY

The methodology for the flood hydrology study of Alamar Creek is based on the use of a deterministic-conceptual model for the conversion of precipitation to runoff. It uses either the standard provided by the HEC-1 model of the U.S. Army Corps of Engineers

(U.S. Army Corps of Engineers 1990), or the equivalent standard with a graphical user interphase, called the HEC-GeoHMS model (U.S. Army Corps of Engineers 1998). The model used in this study is RAINFLO, which emulates the HEC-1 standard and was developed by Dr. Victor M. Ponce in 1986. This model gives comparable results with the HEC-1 model (Lantz 1989) and has been tested in diverse geographical regions, including Baja California (Ponce, et al. 1985; Shetty and Ponce 1997; Ponce, et at. 1999).

The RAINFLO Model

The RAINFLO model has several main characteristics. Generalized topology, which enables the definition of the drainage network using topological numbers for each upstream subbasin (upland watershed) and lateral subbasin (reach watershed), is used without limitation of order. In the case of Alamar Creek, the topology has been defined to a level such that the combined Cottonwood-Alamar Creek main stream of the basin is of the fourth order.

The precipitation can be specified for each subbasin (upstream or lateral) in the form of a rainfall depth (centimeter [cm]) associated with a type of storm (temporal storm distribution), among which are SCS-type storms (U.S. Department of Agriculture) and user-specified storms. The abstraction of precipitation, which in the case of event-based storms consists mostly of infiltration, is performed with the runoff curve number method, a model developed by SCS in 1954 that is of global application (SCS 1985; Ponce and Hawkins, 1996). The conversion of precipitation to runoff is performed by means of the convolution of the effective hyetograph with the SCS unit hydrograph (obtained from the dimensionless SCS unit hydrograph) developed for each subbasin (Ponce 1989). The applicability of this unit hydrograph to basins similar to Cottonwood-Alamar Creek is fully supported by the hydrologic literature and accepted by the Comisíon Nacional del Agua (1993; 1994).

The routing through reservoirs is performed using the storage-indication method (Ponce 1989). In the case of Morena Dam, the flow spills freely as soon as the water level exceeds the crest of the spillway. In the case of Barrett Dam, it is assumed that the floodgates are open during the passage of the flood, following operational practices of the city of San Diego. The routing through river channels is performed using the deterministic Muskingum-Cunge method (Ponce 1989). Contrary to the classical Muskingum method (Chow 1959), which calculates the routing parameters based on the flood record, in the Muskingum-Cunge method the parameters are calculated directly from the channel morphology (slope of the bed and channel cross section). This makes it possible to route the flood through the entire channel network, basing the calculation in physical data and circumventing the necessity of using historic flood data. The use of historic data is impractical because it would require that all streams be gaged. The Muskingum-Cunge method has been accepted by the U.S. Army Corp of Engineers as part of its hydrologic models (U.S. Army Corps of Engineers 1990).

Losses are calculated by infiltration due to the travel in natural channels. These abstractions are known as “channel transmission losses” (Soil Conservation Service

1985). This characteristic makes the model particularly applicable to arroyos (washes) in arid zones, as is the case of the southwestern United States and northwestern part of Mexico. These streams typically abstract (by percolation into the ground) a considerable fraction of the runoff.

Specific Methodology

The methodology followed several steps:

- Compilation of existing maps in California and Baja California, determination of the network topology (i.e., the anatomy of the drainage network) of the basin of Cottonwood-Alamar Creek, and delineation of subbasins (to achieve congruency of scale, it was necessary to convert the 1:50,000-scale maps of the Mexican cartography [INEGI] to the 1:24,000 scale of United States cartography [U.S. Geological Survey, or USGS]; the data was converted to the metric system to provide a uniform system of units)
- Compilation of California precipitation data for return periods from 2 years to 100 years (National Weather Service 1973); digitizing of the precipitation data by subbasin; and extensions to the portion of the basin located in Baja California
- Extension of the precipitation data to return periods of 200 years, 500 years and 1000 years using the method of the extreme values (Gumbel), with adjustment by the method of least squares (Ponce 1989)
- Selection of the SCS storm type I, applicable to Southern and Central California, as design storm; no design storms comparable to those of the United States exist for Mexico
- Calculation of the MMLmean and MMLmax in Morena and Barrett reservoirs, based on the records of water levels provided by the City of San Diego (1912 to 2000 for Morena Dam and 1922 to 2000 for Barrett Dam)
- Collection of cartographic data for soil type and land use in California, which were used to determine the curve number (CN) for each subbasin in California (San Diego County 1980) (for this purpose, the 1:24000-scale maps of "Hydrologic Soil Group—Runoff Potential" and "Ground Cover—Vegetative and Manmade" were used; similar data is not available for the fraction of the basin located in Baja California)
- Evaluation—using stereoscopic pairs, photographic mosaics and field visits—of the soil type and land use conditions in the Mexican portion of the basin, prior to the estimation of the curve number (or this purpose, the soil type and land use in the region located immediately north of the border was used as reference)
- Evaluation, directly from the topographic maps, of the average slope of the land in the subbasins and average slope of the streams that form the drainage network of Cottonwood-Alamar Creek in California and Baja California (the average slope of the land was evaluated following the standard of the San Diego County Hydrology Manual [San Diego County 1985])
- Evaluation of the typical cross-sections of the streams that form the drainage network of the Cottonwood-Alamar Creek, in California and Baja California, by means of field visits, observations, and measurements
- Preparation of RAINFLO input files containing the necessary data to run the model

- Running the model for the 2-, 5-, 10-, 25-, 50-, 100-, 200-, 500-, and 1,000-year frequencies, using the MMLmax in the Morena and Barrett Dams (the difference among the MMLmax and the MMLmean is relatively small, therefore, MMLmax was chosen for the runs; this assumes that the flood occurs at the end of the humid period, placing the calculation on the conservative side)
- Running the model for the 2-, 5-, 10-, 25-, 50-, 100-, 200-, 500-, and 1,000-year frequencies, assuming zero infiltration in the project channelization reach (topological number 40117); this is necessary to evaluate the impact of a postulated concrete channel on the aquifer recharge and the design flood discharge

Data Management
The drainage basin for Cottonwood-Alamar Creek is contained within 17 USGS topographic maps to scale 1:24,000 in San Diego County, and three INEGI topographic maps to scale 1:50,000 in the municipalities of Tijuana and Tecate, reflected on the quadrangle sheets as follows:

- In California, Cuyamaca Peak, Monument Peak, Viejas Mountain, Descanso, Mount Laguna, Sombrero Peak, Dulzura, Barrett Lake, Morena Reservoir, Cameron Corners, Live Oak Springs, Otay Mesa, Otay Mountain, Tecate, Potrero, Campo, and Tierra del Sol
- In Baja California, Valle Redondo, Tecate, and La Rumorosa

The topology of the drainage network for Alamar Creek is shown in Figure 1. In the RAINFLO model, the subbasins are of two types: upstream (upland watershed) and lateral (reach watershed). The topological numbers that characterize the upstream subbasins have two digits, such as 10 for the upland watershed of San Pablo Creek; the topological numbers that characterize the lateral subbasins have five digits, such as 30201 for the first reach watershed of La Posta Creek.

The virtual subbasins are used to enable the printout of results at critical points (downstream of Morena and Barrett Dams and upstream of the channelization project). The null reaches are provided to make possible the joining of two or more tributaries at the same geometric location. The hydrologic characteristics of the subbasins used in the model are shown in Table 2.

The total basin area of the Alamar Creek is 138,710ha, or 1,387.1km^2. Of this area, 26,446ha (19.07%) correspond to upstream subbasins (upland watersheds) and 112,264ha (80.93%) to lateral subbasins (reach watersheds).

The tributary area to Morena Dam measured in this study is 30,704ha, or 22.14% of the total basin. The tributary area to Barrett Dam, excluding Morena, is 31,289ha, or 22.56% of the total basin; therefore, the total tributary area of Barrett Dam is 61,993ha, or 44.69% of the total basin. The area of the “free basin,” which excludes that of Barrett Dam, is 76,717ha. These values are compared with the reported areas by the City of San Diego:

- Morena, 114 square miles or 29,513ha

- Barrett, 134.3 square miles or 34,769ha, excluding Morena; 251.9 square miles or 65,214ha including Morena

It should be mentioned that the National Water Commission considers the tributary area 34,450ha for Barrett Dam (Comisíon Nacional del Agua 1993).

Given the basin area, 24-hour design, storms were selected for the 2-, 5-, 10-, 25-, 50- and 100-year return periods. For each return period, a value of storm precipitation (cm) is obtained at the centroid of each subbasin. The Gumbel method was used to extend the precipitation data beyond 100 years to 200 years, 500 years, and 1,000 years. The results are shown in Table 3. The data on monthly levels for Morena and Barrett Dams for the corresponding record periods (1912 to 2000 for Morena Dam and 1922 to 2000 for Barrett Dam) was analyzed to determine the mean monthly level (MML) for each month of the year, from which the MMLmean and the MMLmax were obtained. This data is shown in Table 4 and Table 5 and Figure 2 and Figure 3.

For Morena Dam, the MMLmax is 122.50ft and MMLmean is 120.09ft; for Barrett Dam, the MMLmax is 121.60ft and MMLmean is 115.42ft. These values are referred to mean sea level and converted to the metric system for their use in the model. For Morena Dam, the MMLmax is 915.894m and MMLmean is 915.159m; for Barrett Dam, the MMLmax is 477.841m and MMLmean is 475.957m.

The data of elevation-volume-discharge for Morena and Barrett Dams were provided for the Department of Water of the City of San Diego. The elevations are referred to mean sea level, and the elevation-volume-discharge data was converted to the metric system for use in the model. Table 6 and Table 7 shows the elevation-volume-discharge data used in the model.

Table 8 shows a typical calculation of runoff curve number, following the procedure established by San Diego (1985). The runoff curve numbers calculated for each subbasin are shown in the last column of Table 2.

The cross-sections were measured in the field during the months of November and December of 2000. In total, 50 cross-sections were measured in San Diego County and the municipalities of Tijuana and Tecate. In some reaches of difficult access, the cross-sections were estimated based on information for similar neighboring basins. The cross-sections and the streambed slope are used to calculate the routing parameters of the Muskingum-Cunge method.

The infiltration velocity, of which the calculation of the channel transmission losses are based, is estimated based on similar experiences and recommendations of hydrology manuals of practice. The NEH-4 Manual (U.S. Department of Agriculture SCS National Engineering Handbook 4) recommends a value of one inch per hour (in/hr) to 3in/hr (0.000007 meters per second [m/s] to 0.000021m/s) in mixtures of sand and gravel with small silt and clay content (Soil Conservation Service 1985). As an additional reference, Matlock (1965) measured velocities of infiltration in the Santa Cruz river in Tucson, Ariz., with values up to 0.000266m/s, although the majority of the values under 0.000088m/s (Ponce, et al. 1986). For purposes of this study, a mean value of 2in/hr (0.000014m/s) was adopted for the streambeds of the Cottonwood-Alamar river basin.

The typical RAINFLO input file, corresponding to the 100-year return period, is shown in Table 9.

RESEARCH RESULTS

The RAINFLO model was used to convert precipitation to runoff under diverse conditions in the Cottonwood-Alamar river basin. The time interval (time step) was fixed at seven-and-a-half minutes, which is considered sufficiently small to numerically resolve the 24-hour storm. The total simulation time was set at five days.

For the channel routing with the Muskingum-Cunge method, the Courant number was controlled equal to or greater than 0.5 to assure numerical stability and equal to or smaller than 2.0 to assure convergence, i.e., the precision and consistency with the diffusive wave equation (Cunge 1969; Ponce and Simons 1977; Ponce, et al. 1978; Ponce and Theurer 1982; Ponce 1989).

The following runs with the model were accomplished:

• Series A: Flood discharges for 2-, 5-, 10-, 25-, 50-, 100-, 200-, 500- and 1,000-year return periods, specifying the MMLmax as initial condition in Morena and Barrett Dams
• Series B: Same as above, but assuming zero infiltration in the channelization project reach (topological number 40117), in order to evaluate the impact of a possible concrete channel upon the aquifer recharge and the design flood discharge

The results of Series A are shown in Table 10. The difference between lines 5 and 6, shown in line 7, corresponds to the local contribution of the channelization project reach (40117). Line 8 shows the adopted flood discharge, rounded to the third significant figure.

The flood hydrographs corresponding to return periods of two years to 1,000 years upstream and downstream of the channelization project are shown in Table 11**.**

The results of Series B are shown in Table 12. From this picture it is concluded that the mean annual discharge corresponding to the two-year return period feeds 0.459 cubic hectometers (hm^3) to the groundwater table, which constitutes 4.6% of the flood runoff volume. The concrete channel would keep this volume in the surface runoff and would increase the peak discharge by $6m^3/s$. Values corresponding to other return periods are indicated in the same table.

In contrast to the volume drained during the flood, the mean annual runoff of Alamar Creek has been calculated as $65.416hm^3$ on the basis of the 1979 to 1992 records (Comisíon Nacional del Agua 1993). Likewise, the volume of water extracted annually from the aquifer of the Tijuana River Basin, including Alamar Creek, is $13.8hm^3$ (Comisíon Nacional del Agua 1997).

Assuming for the mean annual runoff a conservative value of infiltration volume equal to that of the mean annual flood (two-year return period) (4.6%) (Table 12), the postulated channelization would mean an annual volume of equal to or greater than 3.01hm^3 will feed the water table through percolation. This quantity represents 22% of the groundwater resources of the entire Tijuana region, which is a substantial quantity (more than one-fifth of the annual groundwater exploitation would be lost to surface runoff).

Conclusions

The conclusions of this study are shown in Table 10, specifically in line 8, titled "Adopted design discharge." The pertinent authorities should select the appropriate return periods for design purposes. According to current regulations for the delineation of federal zones, the National Water Commission will have to select a return period greater or equal to 10 years, for which the design discharge will not be less than 680m^3/s.

The Instituto Municipal de Planeación (IMPlan) of the City of Tijuana, pending consultation with the pertinent technical authorities, should select an appropriate return period for the design of the channelization project. The interpretation of current regulations permits the establishment of a return period between 50 years and 200 years for populated agricultural zones, assuming a development of this type. Therefore, in this case the design discharge will not be less than 1,140m^3/s and could be as high as 1,420 m^3/s.

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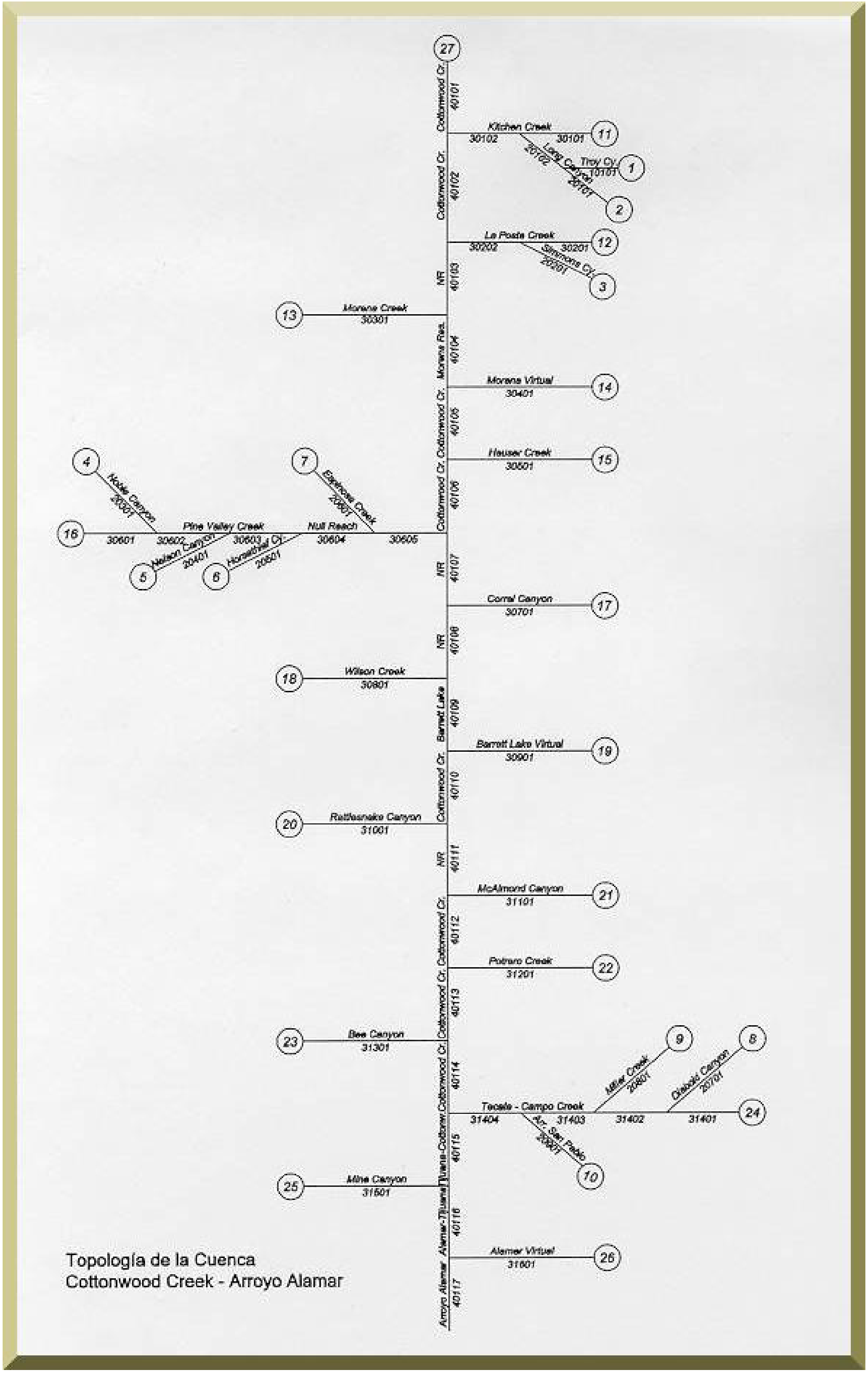

Figure 1. Topology of Cottonwood Creek-Arroyo Alamar Draingage Basin

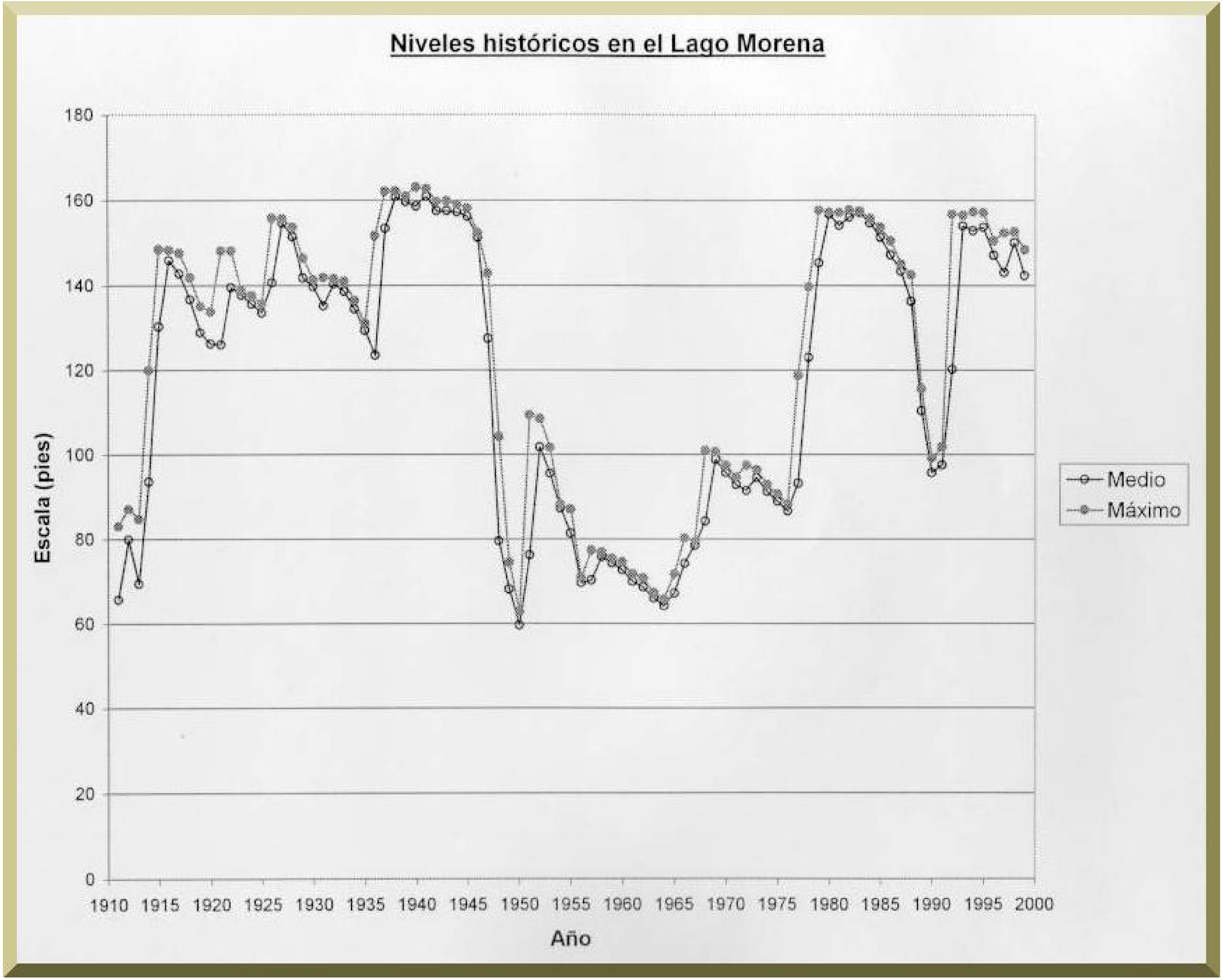

Figure 2. Average and Maximum Historic Monthly Levels in Lake Morena

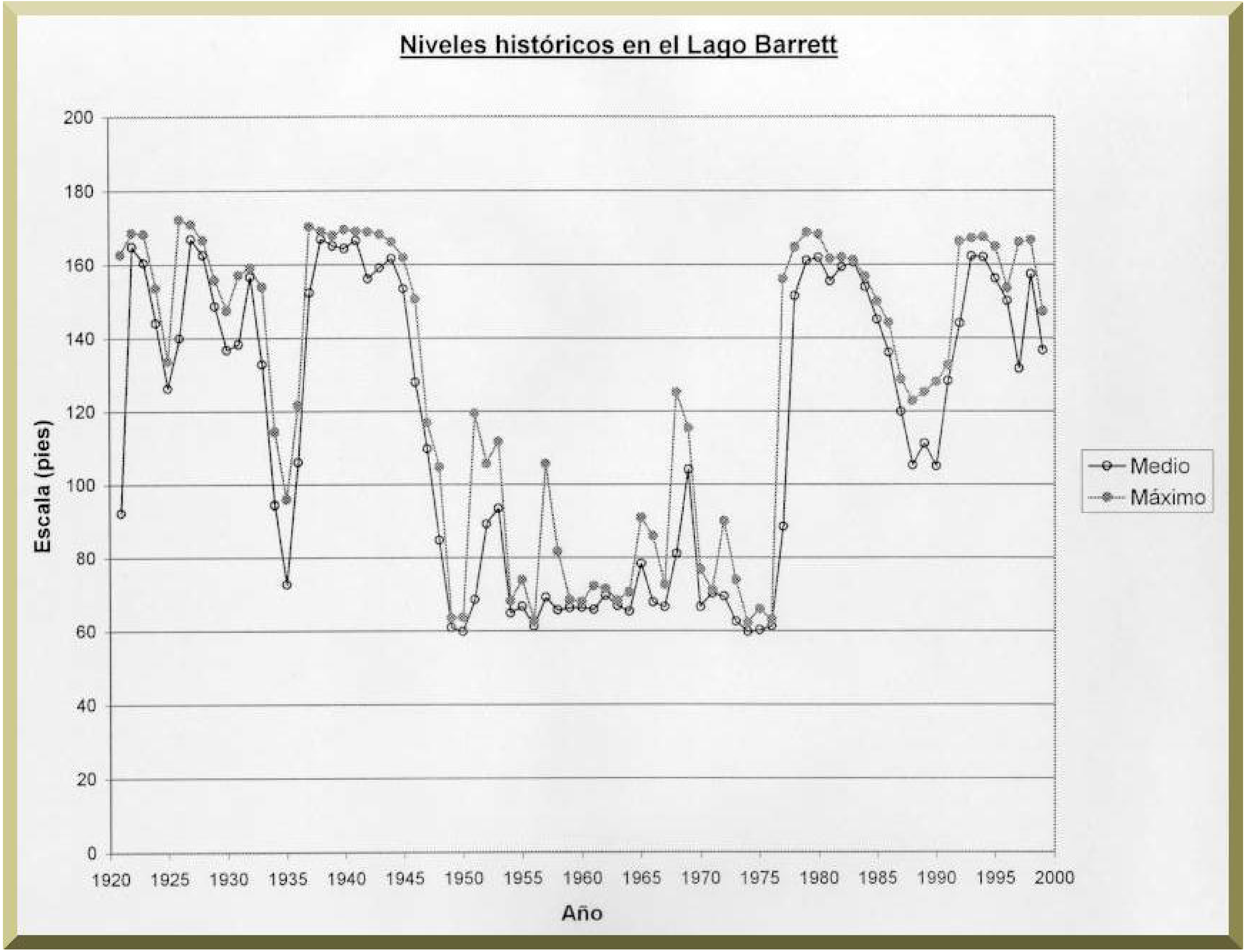

Figure 3. Average and Maximum Historic Monthly Levels in Lake Barrett

Table 1. Flood Discharges (m^3/s) Calculated for the Free Basin of Arroyo Alamar by Statistical Methods[1]

Method/ Return period	5	10	25	50	100	200	500	1000	5000	10000
1. Gumbel Simple (1993)	270	395	554	672	789	905	1059	1175	1444	1560
2. Gumbel II (1993)	76	392	658	836	1007	1176	1396	1561	1942	2102
3. Normal (1993)	287	383	485	551	610	664	729	774	873	912
4. Gumbel II (1994)	300	548	-	960	1123	-	1496	1656	2119	2181

[1] (Comisión Nacional del Agua, 1993; 1994).

Table 2. Hydrologic Characteristics of the Subbasins[1]

Topological number (NTOPO)	Subbasin	Area (ha)	Hydraulic length (m)	Mean slope of the streambed (m/m)	Mean slope of the terrain (%)	Runoff curve number (CN)
10101	Troy Canyon	667	4200	0.0624	25.42	67
20101	Long Canyon 1	805	5040	0.0677	34.67	72
20102	Long Canyon 2	122	2160	0.055	35.56	74
20201	Simmons Canyon	1623	7200	0.0787	18.63	62
20301	Noble Canyon	1976	5760	0.0841	39.9	75
20401	Nelson Canyon	302	2400	0.1168	32.01	80
20501	Horsethief Canyon	1107	8640	0.0423	31.94	78
20601	Espinosa Creek	647	4800	0.0762	35.3	82
20701	Diabold Canyon	949	4320	0.0282	19.8	68
20801	Miller Creek	2428	6360	0.0316	22.72	63
20901	Arroyo San Pablo	5983	16560	0.0217	22.51	82
30101	Kitchen Creek 1	441	3120	0.0498	37.33	76
30102	Kitchen Creek 2	2503	7920	0.0381	39.64	75
30201	La Posta Creek 1	2819	14160	0.0357	31.8	73
30202	La Posta Creek 2	6447	13920	0.0101	24.48	64
30301	Morena Creek	2025	4920	0.0458	27.68	73
30401	Morena Virtual	-	-	-	-	-
30501	Hauser Creek	857	3600	0.0618	35.56	62
30601	Pine Valley Creek 1	1305	6480	0.031	37.7	78
30602	Pine Valley Creek 2	6924	14400	0.0241	28	71
30603	Pine Valley Creek 3	2128	9840	0.0211	40.62	81
30604	Null Reach	-	-	-	-	-
30605	Pine Valley Creek 5	741	5040	0.0194	43.36	73

30701	Corral Canyon	1377	5760	0.0644	26.98	68
30801	Wilson Creek	875	2400	0.0279	35.53	77
30901	Barrett Lake Virtual	-	-	-	-	-
31001	Rattlesnake Canyon	287	3360	0.127	48.91	81
31101	McAlmond Canyon	1155	6480	0.0602	38.45	84
31201	Potrero Creek	4394	12720	0.0367	25.54	76
31301	Bee Canyon	478	2640	0.0623	38.34	82
31401	Campo Creek 1	2146	6960	0.0263	10.71	56
31402	Campo Creek 2	2167	4080	0.0284	16.94	65
31403	Campo - Tecate	13263	21600	0.0134	20.25	69
31404	Arroyo Tecate	8891	26160	0.0153	28.13	84
31501	Mine Canyon	790	4800	0.0546	40.73	85
31601	Alamar Virtual	-	-	-	-	-
40101	Cottonwood Creek 1	2950	9840	0.0242	26.97	74
40102	Cottonwood Creek 2	948	2400	0.0039	20.17	72
40103	Null Reach	-	-	-	-	-
40104	Morena Reservoir	3005	6600	0.0058	19.92	70
40105	Cottonwood Creek 5	652	2760	0.1195	43.58	79
40106	Cottonwood Creek 6	1942	5040	0.0127	30.46	66
40107	Null Reach	-	-	-	-	-
40108	Null Reach	-	-	-	-	-
40109	Barrett Lake	3851	6240	0.0029	37.16	70
40110	Cottonwood Creek 10	707	4920	0.0301	42.33	78
40111	Null Reach	-	-	-	-	-
40112	Cottonwood Creek 12	2598	5880	0.0047	41.04	76
40113	Cottonwood Creek 13	2156	6000	0.0107	35.27	77
40114	Cottonwood Creek 14	1457	3120	0.0098	38.89	79

40115	Cottonwood -Tijuana	432	1680	0.0036	28.58	73
40116	Tijuana - Alamar	5738	11280	0.0079	40.43	83
40117	Arroyo Alamar	7209	9960	0.004	30.06	84
1	Troy Canyon	392	2880	-	22.86	68
2	Long Canyon	364	2040	-	25.04	70
3	Simmons Canyon	373	3360	-	56.83	81
4	Noble Canyon	1363	4800	-	22.4	57
5	Nelson Canyon	400	1560	-	22.36	78
6	Horsethief Canyon	401	1440	-	21.03	75
7	Espinosa Creek	912	2520	-	48.22	80
8	Diabold Canyon	569	3240	-	16.1	59
9	Miller Creek	1062	6120	-	17.79	60
10	San Pablo	4745	6240	-	12.36	84
11	Kitchen Creek	392	2520	-	34.47	74
12	La Posta Creek	1234	6480	-	24.73	65
13	Morena Creek	1754	7680	-	20.45	72
14	Morena Virtual	-	-	-	-	-
15	Hauser Creek	698	3360	-	27.06	74
16	Pine Valley Creek	1646	7680	-	22.86	64
17	Corral Canyon	1191	7920	-	25.04	80
18	Wilson Creek	1688	5880	-	36.94	79
19	Barrett Lake Virtual	-	-	-	-	-
20	Rattlesnake Canyon	313	1560	-	26.9	72
21	McAlmond Canyon	825	3240	-	24.7	72
22	Potrero Creek	2265	8520	-	18.42	70
23	Bee Canyon	917	5400	-	28.49	81
24	Campo Creek	869	4560	-	15.75	56
25	Mine Canyon	233	2400	-	41.36	84
26	Alamar Virtual	-	-	-	-	-
27	Cottonwood Creek	1840	6840	-	34.83	70

[1] The lateral subbasins have a 5-digit NTOPO number; the upland subbasins have up to 2-digit NTOPO number. The "null reach" is a zero-length reach which is used to combine two or more tributaries at the same geometric location.

Table 3. Design Storms (cm) for Return Periods of 2 years to 1000 Years

NTOPO	Subbasin\Return period (years)	2	5	10	25	50	100	200	500	1000
10101	Troy Canyon	11.4	15.2	17.8	22.9	25.4	30.5	32.3	36.4	39.4
20101	Long Canyon 1	11.4	15.2	17.8	22.9	25.4	30.5	32.3	36.4	39.4
20102	Long Canyon 2	11.4	15.2	17.8	22.9	25.4	30.5	32.3	36.4	39.4
20201	Simmons Canyon	8.9	11.4	14	17.8	19.1	21.6	23.6	26.4	28.6
20301	Noble Canyon	11.4	15.2	17.8	22.9	25.4	30.5	32.3	36.4	39.4
20401	Nelson Canyon	8.9	11.4	14	17.8	20.3	21.6	24.2	27.1	29.3
20501	Horsethief Canyon	7.6	10.2	12.7	15.2	17.8	20.3	22	24.7	26.8
20601	Espinosa Creek	7.6	10.2	12.7	15.2	17.8	20.3	22	24.7	26.8
20701	Diabold Canyon	6.4	8.9	9.7	11.4	12.7	15.2	15.9	17.7	19.1
20801	Miller Creek	6.4	8.9	9.7	12.2	14	16.5	17.4	19.6	21.2
20901	Arroyo San Pablo	5.6	8.1	9.4	11.4	12.4	14.2	15.5	17.3	18.7
30101	Kitchen Creek 1	11.4	15.2	17.8	22.9	25.4	30.5	32.3	36.4	39.4
30102	Kitchen Creek 2	11.4	15.2	17.8	22.9	25.4	30.5	32.3	36.4	39.4
30201	La Posta Creek 1	11.4	14	15.2	21.6	22.9	25.4	27.7	30.9	33.4
30202	La Posta Creek 2	10.2	14	15.2	19.1	21.6	24.1	26.1	29.1	31.4
30301	Morena Creek	8.9	11.4	12.7	15.2	19.1	21.6	22.8	25.5	27.6
30401	Morena Virtual	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0
30501	Hauser Creek	6.4	8.9	10.2	14	15.2	17.8	19.3	21.8	23.7
30601	Pine Valley Creek 1	11.4	15.2	17.8	22.9	25.4	30.5	32.3	36.4	39.4
30602	Pine Valley Creek 2	9.7	12.7	15.2	19.6	22.9	25.4	27.8	31.3	34
30603	Pine Valley Creek 3	7.6	10.2	12.7	15.2	17.8	20.3	22	24.7	26.8
30604	Null Reach	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
30605	Pine Valley Creek 5	7.6	10.2	12.7	15.2	17.8	20.3	22	24.7	26.8
30701	Corral Canyon	7.6	10.2	11.9	14	16	21.6	21.5	24.3	26.3
30801	Wilson Creek	6.9	9.7	11.4	14	15.2	16.5	18.4	20.6	22.2
30901	Barrett Lake Virtual	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
31001	Rattlesnake Canyon	6.4	8.9	10.2	13.2	15.2	16.5	18.3	20.6	22.3
31101	McAlmond Canyon	6.4	8.9	10.2	12.7	15.2	16.5	18.2	20.4	22.1

31201	Potrero Creek	6.4	8.9	10.2	12.7	15.2	17.8	18.9	21.4	23.2
31301	Bee Canyon	6.4	8.9	10.2	13.5	15.2	16.5	18.4	20.7	22.4
31401	Campo Creek 1	5.6	8.1	8.9	11.4	12.7	14	15.4	17.2	18.6
31402	Campo Creek 2	5.6	7.6	8.9	10.9	12.2	13.7	14.9	16.7	18
31403	Campo-Tecate	6.4	8.9	9.7	12.7	14	15.7	17.1	19.2	20.7
31404	Arroyo Tecate	6.4	8.9	10.2	12.7	15.2	17.3	18.6	21	22.8
31501	Mine Canyon	6.4	8.9	10.7	14	15.2	16.5	18.6	20.9	22.6
31601	Alamar Virtual	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
40101	Cottonwood Creek 1	10.9	15.2	17.8	21.6	24.1	27.9	30	33.7	36.4
40102	Cottonwood Creek 2	9.4	12.7	14.7	17.8	20.3	22.9	24.7	27.6	29.8
40103	Null Reach	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
40104	Morena Reservoir	7.6	8.9	11.4	14.5	16.5	19.1	20.4	23	25
40105	Cottonwood Creek 5	6.9	9.4	10.2	13.2	15.2	16.5	18.1	20.3	21.9
40106	Cottonwood Creek 6	6.4	8.9	10.2	13.2	15.2	16.5	18.3	20.6	22.3
40107	Null Reach	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
40108	Null Reach	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
40109	Barrett Lake	7.1	9.4	10.2	13.2	15.2	16.5	18	20.2	21.7
40110	Cottonwood Creek 10	6.4	8.9	10.2	12.7	15.2	17.8	18.9	21.4	23.2
40111	Null Reach	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
40112	Cottonwood Creek 12	6.4	8.9	10.2	12.7	15.2	17.8	18.9	21.4	23.2
40113	Cottonwood Creek 13	6.4	8.9	10.2	12.7	15.2	17.8	18.9	21.4	23.2
40114	Cottonwood Creek 14	6.4	8.9	10.2	13.5	15.2	16.5	18.4	20.7	22.4
40115	Cottonwood-Tijuana	6.4	8.9	10.2	13.5	15.2	16.5	18.4	20.7	22.4
40116	Tijuana-Alamar	7.6	10.2	12.7	15.2	17.8	20.3	22	24.7	26.8
40117	Arroyo Alamar	7.6	10.2	12.7	15.2	17.8	20.3	22	24.7	26.8
1	Troy Canyon	11.4	15.2	17.8	22.9	25.4	30.5	32.3	36.4	39.4
2	Long Canyon	11.4	15.2	17.8	22.9	25.4	30.5	32.3	36.4	39.4
3	Simmons Canyon	10.7	12.7	14.7	19.1	21.6	22.9	25.2	28.1	30.3
4	Noble Canyon	11.4	15.2	17.8	22.9	25.4	30.5	32.3	36.4	39.4
5	Nelson Canyon	8.9	12.4	14.5	18.3	21.1	22.9	25.4	28.5	30.8
6	Horsethief Canyon	8.4	11.4	14.7	17.8	20.3	21.8	24.5	27.6	29.9

7	Espinosa Creek	8.1	10.9	13.2	16.5	19.1	21.6	23.5	26.4	28.7
8	Diabold Canyon	7.1	9.7	10.2	12.2	14	15.2	16.4	18.2	19.5
9	Miller Creek	8.4	11.2	12.7	14	16.5	17.8	19.2	21.2	22.8
10	Arroyo San Pablo	5.1	7.6	8.9	10.7	12.2	13.2	14.7	16.5	17.8
11	Kitchen Creek	11.4	15.2	17.8	22.9	25.4	30.5	32.3	36.4	39.4
12	La Posta Creek	10.2	12.7	17.8	22.9	25.4	27.9	31.4	35.5	38.6
13	Morena Creek	9.9	12.7	15.2	19.1	21.8	24.1	26.4	29.6	32
14	Morena Virtual	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
15	Hauser Creek	6.4	8.9	10.7	14	15.2	17.8	19.3	21.8	23.7
16	Pine Valley Creek	10.7	12.7	17.8	22.9	25.4	27.9	31.3	35.3	38.3
17	Corral Canyon	7.6	10.2	10.9	14	15.2	17.8	18.9	21	22.6
18	Wilson Creek	7.6	10.2	12.7	15.2	17.8	20.3	22	24.7	26.8
19	Barrett Lake Virtual	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
20	Rattlesnake Canyon	7.1	10.2	11.4	14	15.2	16.5	18.3	20.4	21.9
21	McAlmond Canyon	6.4	8.9	10.2	12.7	15.2	17.8	18.9	21.4	23.2
22	Potrero Creek	6.4	8.9	10.2	12.7	15.2	17.8	18.9	21.4	23.2
23	Bee Canyon	6.6	8.9	10.7	14	15.2	16.5	18.5	20.8	22.5
24	Campo-Tecate Creek	7.6	10.2	12.7	14	15.2	17.8	19	21.1	22.7
25	Mine Canyon	6.4	8.9	10.7	14	15.2	16.5	18.6	20.9	22.6
26	Alamar Virtual	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
27	Cottonwood Creek	11.4	15.2	17.8	22.9	25.4	30.5	32.3	36.4	39.4

Table 4. Historic Levels (in ft, relative) in Morena Reservoir at the Beginning of the Month[1]

Year	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	Mean
1911-12	65.6	65.5	65	64.5	64.6	65.5	65.5	48.1	50.5	69	80.7	83	65.63
1912-13	83.4	83.5	83.4	83	83.6	83.7	84	85.4	87.1	85.35	59.75	56.8	79.92
1913-14	57.63	57.4	59.1	60.52	61.33	62.84	64.49	72.62	82.67	84.68	84.22	84.7	69.35
1914-15	84.48	83.92	83.29	82.9	82.9	82.98	83.94	90.05	104.36	110.73	113.38	119.93	93.57
1915-16	120.26	119.81	119.14	118.59	118.1	118.04	118.68	148.5	145.15	145.12	144.95	146.08	130.2
1916-17	146.49	146.25	145.33	144.44	144.36	144.09	143.68	145.65	145.89	147.12	148.17	148.29	145.81
1917-18	147.5	146.22	144.55	142.98	141.4	140.4	139.45	139.01	139.13	144.18	144.1	143.03	142.66
1918-19	141.77	140.1	138.8	136.94	135.62	134.79	134.77	134.68	135.53	136.42	135.95	134.57	136.66
1919-20	132.47	130.51	128.28	126.67	126.26	126.16	124.45	123.4	126.7	131.94	134.52	135.02	128.87
1920-21	133.8	131.67	129.78	127.87	126.26	124.84	124.29	124.51	123.88	123.22	121.98	121.74	126.15
1921-22	120	118.2	115.72	113.37	111.38	108.76	120.82	125.99	136.65	145.07	147.62	148.02	125.97
1922-23	148.01	146.83	145.22	143.08	137.21	133.55	133.98	134.52	136.26	137.73	138.87	138.64	139.49
1923-24	138.26	138.03	137.51	137.2	136.92	136.8	137.07	137.18	137.09	138.1	138.74	138.28	137.6
1924-25	137.57	136.86	136.14	135.45	135.04	134.7	135.11	135.08	135.15	135.24	135.49	135.03	135.57
1925-26	134.68	133.91	133.19	132.58	132.63	132.51	132.44	132.54	133.01	132.91	135.59	135.26	133.44
1926-27	134.62	133.87	133.22	132.58	132.07	131.82	132.97	133.22	155.34	155.35	155.35	155.74	140.51
1927-28	155.49	154.46	154.22	153.73	153.57	153.69	154.69	154.96	155.08	155.01	154.75	154.35	154.5
1928-29	153.61	152.83	152.1	151.42	150.93	150.59	150.72	151.02	151.48	151.89	150.93	148.7	151.35
1929-30	146.31	144.15	142.58	141.07	140.33	139.83	139.62	140.71	140.81	141.32	141.2	141.87	141.65
1930-31	141.32	140.78	140.16	139.6	139.14	139.1	138.82	139.02	139.76	139.52	139.41	138.92	139.63
1931-32	138.28	137.6	134.14	130.28	128.78	128.91	129.69	130.21	139.08	141.05	141.72	141.74	135.12
1932-33	141.45	140.72	139.99	139.35	138.9	138.57	139.28	140.48	140.93	141.03	141.29	141.39	140.28
1933-34	140.86	140.1	139.4	138.8	138.35	138	138.07	137.99	138.23	138.01	137.57	136.89	138.52
1934-35	136.39	135.68	135.16	134.56	134.2	133.96	133.9	134.26	135.2	136.21	131.71	131.59	134.4
1935-36	130.99	130.35	129.99	129.44	128.91	128.64	128.48	128.33	129.78	130.12	130.67	125.98	129.31
1936-37	119.98	112.78	109.81	109.43	109.42	109.04	111	114.02	138.05	145.96	150.09	151.61	123.43
1937-38	151.82	151.49	150.89	150.27	149.76	149.46	149.69	149.99	151.88	160.38	161.5	161.97	153.26
1938-39	161.66	161.2	160.52	159.85	159.32	158.78	159.65	160.47	161.62	162.02	162.09	161.7	160.74
1939-40	160.88	159.91	159.23	159.39	158.9	158.74	158.64	159.08	160.07	160.15	160.3	159.63	159.58
1940-41	158.82	157.91	156.98	156.34	155.97	154.92	157.07	157.35	158.72	163	162.84	162.6	158.54
1941-42	162.59	162.38	162.09	161.62	161.93	161.98	159.69	159.55	159.62	159.54	159.6	159.28	160.82
1942-43	158.7	157.91	157.02	156.26	155.7	155.34	155.33	157.35	157.78	159.44	159.58	159.14	157.46
1943-44	158.64	157.85	157.03	156.32	155.75	155.19	155.62	155.74	158.22	159.67	159.73	159.53	157.44
1944-45	158.98	158.17	157.22	156.39	155.71	156.26	156	155.83	156.02	158.26	158.91	158.58	157.19
1945-46	158.1	157.37	157.53	157.01	156.5	156.21	155.66	155.98	156.16	155.87	154.51	152.9	156.15
1946-47	152.32	152.02	151.41	150.98	150.66	151.18	151.49	151.53	151.59	151.16	150.42	149.56	151.19
1947-48	142.83	141.51	139.63	132.8	131.5	130.43	129.73	126.76	119.88	120.43	107.88	106.13	127.46
1948-49	104.15	100.05	91.8	68.22	69.01	69.27	70.28	74.2	78.8	82.25	72.52	73.13	79.47
1949-50	72.99	72.61	72.28	72.03	72.14	72.48	73.25	74.45	63.9	54.9	57.42	58.41	68.07
1950-51	58.39	57.95	57.28	57.13	57.5	58.36	59.06	60.58	61.32	61.96	62.74	62.75	59.59
1951-52	62.43	62.14	61.86	61.48	61.47	61.78	63.72	77.16	78.57	104.5	108.83	109.29	76.1

1952-53	108.53	101.43	100.78	100.25	99.8	100.03	100.45	100.98	101.29	102.09	102.38	102.15	101.68
1953-54	101.59	100.97	100.39	99.81	99.21	99.13	98.91	99.56	81.82	87.41	88.58	88.52	95.49
1954-55	88.14	87.75	87.2	86.73	86.45	86.51	86.59	87.4	87.6	87.7	87.7	87.5	87.27
1955-56	87	86.6	86.1	85.5	85.1	85.1	85.4	85.9	73.94	71.22	71.7	71.5	81.26
1956-57	70.8	70.1	69.4	68.7	68.4	68	68	69.7	70.1	70.4	70.4	70.5	69.54
1957-58	69.8	69.1	68.5	67.9	67.9	67.9	68.1	68.3	69.2	72.1	76.6	77.3	70.23
1958-59	76.9	76.2	75.6	75.1	74.6	74.9	74.9	75.2	76.6	76.6	76.4	76	75.75
1959-60	75.3	74.6	73.9	73.4	73.1	72.8	73.2	73.9	75	75.2	75.3	75.1	74.23
1960-61	74.5	73.8	73	72.6	72.1	72.2	72.2	72.3	72.3	72.4	72.1	71.5	72.58
1961-62	70.8	70	69.5	68.8	68.4	68.2	68.5	69.1	70.5	71.7	71.5	71.2	69.85
1962-63	70.7	69.9	69.2	68.6	68.1	67.9	67.8	67.7	68.2	68.4	68.4	67.8	68.56
1963-64	67.2	66.4	65.8	65.4	65.4	65.4	65.3	65.6	65.7	66.3	66.5	66.2	65.93
1964-65	65.6	64.8	64.1	63.5	63.1	63.1	63.3	63.4	63.8	64	65.7	65.2	64.13
1965-66	64.8	64	63.3	62.8	62.3	66	67.9	69.3	70.8	71.6	71.4	71	67.1
1966-67	70.4	69.6	68.85	68.3	67.8	67.8	78.6	79.1	79.2	79.4	80.2	80	74.1
1967-68	79.4	78.8	78.3	77.98	77.5	77.7	78.4	78.53	78.67	78.81	78.66	78.24	78.42
1968-69	77.62	77.03	76.35	75.73	75.33	75.18	75.41	81.55	96.68	97.72	100.3	100.95	84.15
1969-70	100.63	100.02	99.3	98.78	98.33	98.19	98.17	98.25	98.21	98.68	98.55	97.97	98.76
1970-71	97.37	96.63	96.05	95.38	94.94	94.78	95.5	95.5	95.59	95.57	95.33	95.12	95.65
1971-72	94.6	93.8	93.6	93	92.6	92.3	92.9	92.7	92.7	92.4	91.9	91.4	92.83
1972-73	91.1	89.9	89.3	88.8	88.7	88.9	89.3	89.5	90.3	96.5	97.4	97.1	91.4
1973-74	96.4	95.6	94.9	94.3	93.8	93.5	93.8	94.6	94.5	94.4	94.1	93.6	94.46
1974-75	92.8	92.2	91.3	90.9	90.7	90.54	90.6	90.52	90.72	91.4	91.7	91.2	91.22
1975-76	90.65	89.9	89.05	88.66	88.12	88	87.96	87.8	88.8	89.18	89.3	88.92	88.86
1976-77	88.2	87.58	86.88	86.79	86.3	86.06	85.82	86.34	86.34	86.3	86.01	85.99	86.55
1977-78	85.29	84.54	84	83.33	82.91	82.6	82.8	85.4	98.04	111.9	117.7	118.6	93.09
1978-79	118.1	117.5	116.4	116	115.55	116	117.8	120.5	125.6	134.6	138.4	139.6	123
1979-80	140	139.45	138.73	137.89	137.18	137.51	137.7	144.5	157.55	157.5	157.4	157.22	145.22
1980-81	157.12	157.14	156.84	156.41	155.96	155.82	156.16	156.53	157.05	157.08	157.05	156.4	156.63
1981-82	155.79	154.64	153.7	152.68	151.87	151.62	151.4	152.45	153.58	156.24	157	157.04	154
1982-83	156.49	155.56	154.84	154.67	153.5	153.52	156.4	157.32	157.6	157.64	157.5	157.3	156.03
1983-84	157.2	157.15	157.18	157.17	157	157.23	157.35	156.84	157	156.9	156.9	156.5	157.04
1984-85	155.6	155.34	154.85	154.13	153.73	153.62	154.25	154.5	154.9	155.22	155.1	154.55	154.65
1985-86	153.65	152.72	151.47	150.67	150	149.9	150.14	149.88	150.83	152.4	152.2	151.48	151.28
1986-87	150.46	149.32	148.32	147.45	146.84	146.37	146.2	146.16	146.15	146.66	146.38	145.77	147.17
1987-88	145	144.15	143.38	142.75	142.61	142.53	142.5	143.3	143.64	143.4	143.63	143.2	143.34
1988-89	142.45	141.62	140.9	140.17	139.55	138.95	137.63	136	135.69	132.04	127.3	121.71	136.17
1989-90	115.55	115	114.31	113.87	113.43	113.02	112.83	113.02	113.18	99.88	99.93	99.6	110.3
1990-91	99.08	98.4	97.72	97.28	96.85	96.6	96.69	96.74	81.08	92.15	97.84	97.77	95.68
1991-92	97.36	96.78	96.31	95.84	95.38	95.2	95.5	95.82	97.93	100.32	101.68	101.58	97.48
1992-93	100.74	100.1	99.58	99.04	98.6	98.21	98.4	132.68	147.24	153.94	156.15	156.69	120.11
1993-94	156.48	155.58	154.44	153.37	152.44	151.96	152.3	152.55	153.68	154.53	154.73	154.39	153.87
1994-95	153.59	152.4	151.62	150.66	149.6	149.1	148.84	151.58	154.23	157.26	157.24	157.2	152.78
1995-96	157.08	156.22	155.14	154.06	153.26	152.7	152.4	152.4	152.7	152.94	152.54	151.7	153.6
1996-97	150.52	149.58	148.26	147.34	146.52	146.18	145.84	146.4	146.48	146.18	145.7	144.96	147
1997-98	144.06	143.1	142.08	141.4	140.52	140.28	138.76	137.07	141.62	144.88	150.42	152.25	143.04
1998-99	152.51	151.87	151.04	150.05	149.3	149.12	149.12	149.22	149.27	149.28	149.52	149.11	149.95

1999-00	148.37	147.4	146.46	145.55	144.67	144.04	143.6	141.88	140.08	137.8	135.13	131.87	142.24
Mean	121.51	120.53	119.6	118.53	117.96	117.75	118.21	119.38	120.72	122.25	**122.5**	122.14	**120.09**

[1] The first 5 yr were not included in the calculation of the mean due to the initial filling of the reservoir. The mean mean monthly level (120.09 ft) and the maximum mean monthly level (122.5 ft) (May) are shown in bold in the last line of the table.

Table 5. Historic Levels (in ft, relative) in Barrett Reservoir at the Beginning of the Month[1]

Year	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	Mean
1921-22	47.9	47.95	48.04	48.35	49.1	49.9	101.82	108.56	132.3	149.25	159.4	162.63	92.1
1922-23	161.68	160.43	159.56	158.97	163.65	165.95	168.41	167.35	167.04	167.76	168.35	168.47	164.8
1923-24	168.25	167.81	167.27	166.81	163.63	161.43	158.56	155.47	153.19	153.38	154.5	154.19	160.37
1924-25	153.6	152.92	152.27	151.69	149.02	146.15	143.48	140.1	137.12	134.68	134	133.86	144.07
1925-26	133.54	132.86	132.2	131.64	129.37	124.86	120.88	116.18	117.25	117.38	128.84	129.24	126.19
1926-27	128.77	127.95	127.28	126.67	125.43	121.75	121.68	119.68	164.3	171.25	172.09	171.78	139.89
1927-28	170.89	169.91	168.22	167.72	165.73	163.58	163.37	164.26	166	167.14	167.25	167.07	166.76
1928-29	166.56	165.96	165.37	164.87	164.62	164.61	164.63	161.93	159.86	157.8	157.62	156.56	162.53
1929-30	155.71	153.79	151.71	149.93	149.9	146.18	143.16	144.73	145.08	146.75	146.95	149.24	148.59
1930-31	147.33	146.35	144.34	139.98	135.7	131.97	130.98	131.45	133	133.05	133.21	132.96	136.69
1931-32	132.46	131.93	132.71	132.97	130.14	125.98	125.58	127.18	150.3	155.02	156.57	157.06	138.16
1932-33	156.96	156.38	155.73	155.19	154.9	154.67	155.3	157.05	158.17	158.69	159.04	156.9	156.58
1933-34	153.77	149.86	145.81	141.56	137.2	132.66	128.28	123.1	123.49	123.49	120.26	113.76	132.77
1934-35	107.21	98.29	92.8	92.8	90.95	79.75	80.69	82.61	90	95.19	114.32	106.15	94.23
1935-36	95.78	82.47	67.15	59.4	61.7	62.5	63.37	64.21	76.76	80.38	79.46	78.43	72.63
1936-37	80.31	82.4	70.75	112.74	111.6	110.52	111.66	113.17	116.58	120.23	121.6	120.07	105.97
1937-38	116.78	114.51	112.04	165.9	164.53	162.1	159.81	160.02	162.56	168.93	169.81	170.1	152.26
1938-39	168.5	167.94	167.73	167.51	165.65	163.49	163.77	163.86	167.7	168.93	168.62	167.35	166.75
1939-40	165.86	164.2	162.55	163.31	163.36	163.39	163.7	164.65	166.58	167.55	167.7	166.76	164.97
1940-41	165.25	163.7	161.29	159.86	159.83	161	164.62	163.37	164.45	169.4	169.3	168.88	164.25
1941-42	168.29	166.15	164.28	163.53	163.46	161.98	168	168.47	168.96	168.9	168.57	166.48	166.42
1942-43	163.68	160.78	112.04	155.82	155.83	155.19	155.21	158.21	158.23	161	168.65	168.77	156.12
1943-44	165.68	162.49	159.38	156.41	153.63	151.04	149.4	150.3	158.52	166.7	168.1	167.02	159.06
1944-45	164.92	162.1	159.77	158.33	158.44	160.08	158.85	159.96	161.42	166.04	165.71	163.36	161.58
1945-46	161.8	158.62	155.58	152.07	151.19	146.97	154.02	152.36	150.77	151	153.06	152.83	153.36
1946-47	150.51	146.77	142.44	138.51	134.26	131.56	127.97	123.18	118.88	114.38	107.52	98.9	127.91
1947-48	115.32	109.62	104.95	116.37	110.66	104.58	103.22	104.08	113.17	107.03	116.74	110.55	109.69
1948-49	104.06	104.6	102.51	101.25	91.85	76.67	63.98	70.72	76.69	82.21	78.3	62.57	84.62
1949-50	60.07	60.02	59.91	59.72	60.05	60.68	61.63	63.4	60.41	61.11	61.16	61.83	60.83
1950-51	61.74	61.49	61.09	60.95	60.89	61.22	61.59	62.78	63.52	59.91	58.09	43.77	59.75
1951-52	41.97	42.27	42.31	42.19	42.52	43.25	58.61	84.68	72.7	116.4	119.46	114.51	68.41
1952-53	105.62	103.12	89.8	81.08	81.12	81.82	83.65	85.85	86.89	89.2	90.04	90.39	89.05
1953-54	90.09	89.54	89.01	88.57	88.3	88.31	88.29	89.97	102.61	111.72	103.46	89.64	93.29
1954-55	67.37	62.18	62.27	62.26	62.48	62.95	63.49	65	66.2	67.3	67.6	68.1	64.77
1955-56	67.7	67.6	67.2	66.9	66.7	66.9	67.3	67.8	73.8	60.7	62.7	62.9	66.52
1956-57	62.6	62.1	61.7	61.3	61.2	61.1	61.3	60.9	59.2	60.4	60.8	61.7	61.19
1957-58	61.4	60.8	60.3	60	60.1	60.2	60.4	60.6	62.8	79.7	105.6	96	68.99
1958-59	81.6	62.4	62.5	62.4	62.3	62.6	63	63.5	66.4	66.9	67	66.8	65.62
1959-60	66.4	65.9	65.4	65.1	64.8	64.7	65	65.5	67.3	68.1	68.3	68.3	66.23
1960-61	67.8	67.2	66.6	66.1	65.9	66	66	66.1	66.1	66.2	65.9	65.5	66.28
1961-62	64.9	64.3	63.7	63.3	63	62.9	63.1	63.5	64.9	71.5	72.1	71.9	65.76
1962-63	71.4	70.7	70.1	69.6	69.2	69	69	68.9	69.2	69.2	69.1	68.7	69.51
1963-64	68.2	67.4	66.8	66.6	66.5	66.5	66.4	66.6	66.6	66.8	66.7	66.4	66.79
1964-65	65.9	65.2	64.6	64	63.7	63.7	63.9	63.9	64	64	70.5	70.1	65.29
1965-66	69.7	69.1	68.5	68.1	67.7	75.7	79.56	83.01	88.21	90.56	90.87	87.18	78.18

1966-67	68.3	60.86	60.52	60.22	60.07	60.16	85.89	81.17	72.02	61.2	70.03	72.31	67.73
1967-68	72.45	71.89	71.3	70.9	70.47	70.67	64.75	60.95	61.68	60.34	61.07	60.9	66.45
1968-69	60.44	59.96	59.38	58.9	58.67	58.66	58.86	78.77	107.72	125.11	124.16	120.55	80.93
1969-70	115.35	110.79	104.29	104.04	103.84	103.91	104	104.24	104.56	105.74	98.55	88.4	103.98
1970-71	76.68	60.74	60.78	60.47	60.46	60.96	66.06	68.1	69.55	70.59	71.18	71.5	66.42
1971-72	71.12	70.59	70.15	69.71	69.51	69.47	70.35	70.72	71.04	70.93	70.72	67.18	70.12
1972-73	61.07	60.58	60.04	59.7	59.86	62.5	65.62	67.08	72.33	89.9	89.3	83.56	69.3
1973-74	73.8	61.17	60.1	59.82	59.68	59.9	60.05	65.3	65.86	62.66	60.6	60.42	62.45
1974-75	59.95	59.52	58.98	58.56	58.64	58.6	58.99	59.12	59.7	62.14	60.66	60.44	59.61
1975-76	60.11	59.6	59.04	58.59	58.34	58.45	58.56	58.88	65.8	63.75	60.3	59.91	60.11
1976-77	59.46	59.1	58.58	61.18	60.92	60.88	60.88	62.01	62.21	62.96	62.9	63.04	61.18
1977-78	62.52	61.86	61.54	61.07	60.8	60.63	60.87	73.8	97.07	149.06	154.59	156	88.32
1978-79	154.08	151.5	148.28	146.3	143.75	142.1	141.26	144.08	151.64	163.88	163.88	164.7	151.29
1979-80	163.56	161.8	159.86	157.78	156.86	156.96	157.22	161.62	161.9	161.54	164.22	168.74	161.01
1980-81	168.12	166.96	164.82	163.12	161.46	159.76	158.6	157.48	157.48	161.02	161.92	161.22	161.83
1981-82	159.38	157.22	155.2	153.12	151.16	149.44	149.62	151.9	154.7	159.86	161.6	160.96	155.35
1982-83	159.58	159.26	157.64	155.92	154.56	155.52	161.06	161.34	161.86	161.86	161.58	161.26	159.29
1983-84	161.1	160.86	160.93	160.52	160.93	161.02	161.1	161	160.94	160.32	159.1	157.47	160.44
1984-85	156.72	155.76	154.8	152.68	151.74	151.12	153.34	154.59	154.92	154.58	153.62	151.88	153.81
1985-86	149.84	148.04	146.18	144.14	142.5	142.52	142.1	140.76	142.62	147.48	147.88	146.11	145.01
1986-87	144.04	141.94	139.9	138.3	136.96	135.48	134.1	132.94	132.84	133.06	131.98	130.02	135.96
1987-88	128.71	127.44	125.3	122.73	120.68	118.89	117.2	117.75	116.72	114.61	114.32	112.85	119.77
1988-89	108.21	103.87	103.8	100.18	93.83	93.07	99.52	104.45	104.68	111.01	116.55	122.71	105.16
1989-90	125.11	121.32	116.7	112.17	109.58	105.22	100.58	101.14	101.5	115.87	113.84	110.26	111.11
1990-91	106.54	103.9	101.02	96.22	92.72	92.72	92.94	93.21	99.98	123.88	127.66	127.96	104.9
1991-92	127.68	127.23	126.77	126.41	126.12	125.93	126.13	126.74	129.07	131.44	132.5	132.26	128.19
1992-93	131.76	131.19	130.7	130.2	129.92	129.64	129.98	161.28	161.55	161.26	163.51	166.17	143.93
1993-94	167.04	166.34	165.8	162.6	158.82	159.58	160.46	161	161.02	161.03	161.06	161	162.15
1994-95	160.92	160.92	160.9	160.93	160.95	160.94	160.96	161.04	160.98	161.23	165.82	167.4	161.92
1995-96	164.8	161.56	158.46	157.6	158.02	155.86	153.8	151.91	153.31	154.68	152.62	150.77	156.12
1996-97	150.88	151	151.05	151.18	151.45	151.96	152.52	153.48	151.96	148.56	144.9	141.24	150.02
1997-98	136.72	132.25	127.46	123.16	116.66	110.64	111.56	110.88	134.46	146.2	162.29	165.94	131.52
1998-99	166.42	164.44	161.76	161.08	158.85	156.78	156.14	155.28	153.92	152.17	151.33	149.4	157.3
1999-00	147.14	144.84	141.92	138.74	135.66	132.86	129.52	128.55	133.3	135.19	135.58	135	136.53
Media	117.66	115.36	112.87	113.57	112.4	111.29	111.79	113.23	116.38	119.86	**121.6**	120.07	**115.42**

[1] The first 10 months were not included in the calculation of the mean due to the initial filling of the reservoir. The mean mean monthly level (115.42 ft) and the maximum mean monthly level (121.6 ft) (May) are shown in bold in the last line of the table.

Table 6. Funtions of Elevation -stored Volume-spilled Discharge for Morena Reservoir[1]

Relative level (ft)	Absolute level (ft)	Volume stored (acre ft)	Spilled discharge ft3/s)	Absolute level (m)	Stored volume (m3)	Spilled discharge (m3/s)
117.6	3000	11740	0	914.4	14481076	0
120.6	3003	13300	0	915.314	16405308	0
123.6	3006	15050	0	916.229	18563902	0
126.6	3009	17010	0	917.143	20981526	0
129.6	3012	19180	0	918.058	23658182	0
132.6	3015	21590	0	918.972	26630872	0
135.6	3018	24240	0	919.886	29899600	0
138.6	3021	27150	0	920.801	33489032	0
141.6	3024	30280	0	921.715	37349828	0
144.6	3027	33630	0	922.63	41481992	0
147.6	3030	37200	0	923.544	45885524	0
150.6	3033	41040	0	924.458	50622092	0
153.6	3036	45160	0	925.373	55704040	0
156.6	3039	49590	0	926.287	61168364	0
157	3039.4	50206	0	926.409	61928188	0
157.6	3040	51130	486	926.592	63067924	13.76
158.6	3041	52700	2117	926.897	65004492	59.95
159.6	3042	54300	4386	927.202	66978064	124.2
160.6	3043	55930	7145	927.506	68988640	202.32
161.6	3044	57580	10633	927.811	71023880	301.09
162.6	3045	59250	14283	928.116	73083800	404.45
163.6	3046	60950	18812	928.421	75180720	532.7
164.6	3047	62670	23246	928.726	77302304	658.25
165.6	3048	64410	28781	929.03	79448560	814.99
166.6	3049	66180	33944	929.335	81631824	961.19

167.6	3050	67980	40478	929.64	83852096	1146.21
168.6	3051	69800	46339	929.945	86097032	1312.17
169.6	3052	71650	53876	930.25	88378968	1525.6
170.6	3053	73520	60416	930.554	90685584	1710.79
171	3053.4	74300	63101	930.676	91647696	1786.82

[1] The data in the first four columns was supplied by the Water Department of the City of San Diego.

Table 7. Functions of Elevation-stored Volume-spilled Discharge for Barrett Reservoir[1]

Relative level (ft)	Absolute level (ft)	Volume stored (acre ft)	Spilled discharge (ft3/s)	Absolute level (m)	Stored volume (m3)	Spilled discharge (m3/s)
115	1561.1	11023	0	475.823	13596670	0
118	1564.1	12175	0	476.738	15017641	0
121	1567.1	13401	0	477.652	16529890	0
124	1570.1	14703	0	478.566	18135884	0
127	1573.1	16088	0	479.481	19844256	0
130	1576.1	17565	0	480.395	21666108	0
133	1579.1	19137	0	481.31	23605142	0
136	1582.1	20802	0	482.224	25658888	0
139	1585.1	22553	0	483.138	27818716	0
142	1588.1	24388	0	484.053	30082154	0
145	1591.1	26308	0	484.967	32450440	0
148	1594.1	28315	0	485.882	34926036	0
151	1597.1	30411	0	486.796	37511416	0
154	1600.1	32597	0	487.71	40207808	0
157	1603.1	34872	0	488.625	43013976	0
160	1606.1	37236	0	489.539	45929928	0
160.9	1607	37955	0	489.814	46816804	0
161	1607.1	38044	39	489.844	46926584	1.1
162	1608.1	38861	1407	490.149	47934336	39.84
163	1609.1	39688	3712	490.454	48954428	105.11
164	1610.1	40525	6380	490.758	49986852	180.66
165	1611.1	41373	9388	491.063	51032844	265.84
166	1612.1	42230	13218	491.368	52089936	374.29

167	1613.1	43097	17029	491.673	53159364	482.21
168	1614.1	43974	21318	491.978	54241128	603.66
169	1615.1	44861	25735	492.282	55335228	728.73
170	1616.1	45759	30438	492.587	56442896	861.91
171	1617.1	46667	35596	492.892	57562896	1007.96
172	1618.1	47585	41187	493.197	58695232	1166.28
173	1619.1	48513	47148	493.502	59839904	1335.08
174	1620.1	49451	53432	493.806	60996908	1513.02
175	1621.1	50500	60013	494.111	62290832	1699.38
176	1622.1	51550	66874	494.416	63585988	1893.66
177	1623.1	52610	74001	494.721	64893480	2095.47
178	1624.1	53680	81384	495.026	66213304	2304.53
179	1625.1	54751	89012	495.33	67534360	2520.53

[1] The data in the first four columns was supplied by the Water Department of the City of San Diego.

Table 8. Calculation of Runoff Curve Number for Pine Valley Creek 2 Lateral Subbasin (topological number 30602)[1]

Symbol	Ground cover/land use	Hydrologic condition	Soil group	CN	No. of grid points	Partial CN
IP	Irrigated Pasture	good	A	33		
			B	58		
			C	72	1	0.396
			D	79		
AG	Annual Grass	good	A	38	1	0.209
			B	61	2	0.67
			C	74	2	0.813
			D	80		
BC	Broadleaf Chaparral	good	A	31		
			B	57		
			C	71	1	0.39
			D	78		
NC	Narrowleaf Chaparral	fair	A	55	10	3.022
			B	72	2	0.791
			C	81	53	23.588
			D	86	66	31.187
OB	Open Brush	good	A	41	1	0.225
			B	63		
			C	75		
			D	81		
WO	Woodland	good	A	28	25	3.846

			B	55	4	1.209
			C	70	7	2.692
			D	77		
WG	Woodland Grass	good	A	33	1	0.181
			B	58	2	0.637
			C	72	1	0.396
			D	79		
ME	Meadow	good	A	30		
			B	58	2	0.637
			C	84		
			D	78		
PG	Perennial Grass	good	A	38		
			B	61		
			C	74	1	0.407
			D	80		
	Total				182	71

[1] The method is explained in the Hydrology Manual of San Diego County (1985).

Table 9. RAINFLO Input File Corresponding to the 100-year Return Period

```
'r02' 'proyecto encauzamiento del arroyo alamar'
'r04' '21/dic/00, 1120, 100 años, infiltración en 40117'
'r10' 0 1 1 0 2 0 1 1 1 1 1 0 1 53 960 120. 1500.
'r21' 01 10101 2 0 'troy canyon'
'r30' 0. 2100. 0.0624 0.000014 4 0.0 0.050 0.0 0. 24.
'r34' 0. 10. 10. 0. 14. 0. 24. 10.
'r30' 0. 2100. 0.0624 0.000014 4 0.0 0.050 0.0 0. 24.
'r34' 0. 10. 10. 0. 14. 0. 24. 10.
'r40' 67. 667. 25.42 1.
'r45' 30.5 24.
'r21' 02 20101 1 0 'long canyon 1'
'r30' 0. 5040. 0.0677 0.000014 4 0.0 0.050 0.0 0. 24.
'r34' 0. 10. 10. 0. 14. 0. 24. 10.
'r40' 72. 805. 34.67 1.
'r45' 30.5 24.
'r21' 03 20102 1 0 'long canyon 2'
'r30' 0. 2160. 0.0550 0.000014 8 0.050 0.050 0.050 10. 19.
'r34' 0. 5.5 6. 1.5 10. 1.5 13. 0. 16. 0. 19. 1.5 23. 1.5 29. 5.5
'r40' 74. 122. 35.56 1.
'r45' 30.5 24.
'r21' 04 20201 1 0 'simmons canyon'
'r30' 0. 7200. 0.0787 0.000014 4 0.0 0.04 0.0 0. 18.
'r34' 0. 4. 4. 0. 14. 0. 18. 4.
'r40' 62. 1623. 18.63 2.
'r45' 21.6 24.
'r21' 05 20301 1 0 'noble canyon'
'r30' 0. 6480. 0.031 0.000014 8 0.100 0.050 0.100 25. 35.
'r34' 0. 8.5 5. 3.5 25. 1.5 28. 0. 32. 0. 35. 1.5 55. 3.5 60. 8.5
'r40' 75. 1976. 39.90 2.
'r45' 30.5 24.
'r21' 06 20401 1 0 'nelson canyon'
'r30' 0. 2400. 0.1168 0.000014 4 0.0 0.05 0.0 0. 13.
'r34' 0. 5. 5. 0. 8. 0. 13. 5.
'r40' 80. 302. 32.01 1.
'r45' 21.6 24.
'r21' 07 20501 1 0 'horsethief canyon'
'r30' 0. 8640. 0.0423 0.000014 6 0.060 0.050 0.060 20. 35.
'r34' 0. 5. 20. 3. 26. 0. 29. 0. 35. 3. 55. 5.
'r40' 78. 1107. 31.94 1.
'r45' 20.3 24.
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'r21' 08 20601 1 0 'espinosa creek'
'r30' 0. 4800. 0.0762 0.000014 4 0.0 0.05 0.0 0. 13.
'r34' 0. 5. 5. 0. 8. 0. 13. 5.
'r40' 82. 647. 35.30 1.
'r45' 20.3 24.
'r21' 09 20701 2 0 'diabold canyon'
'r30' 0. 1440. 0.0282 0.000014 8 0.040 0.030 0.040 12. 17.
'r34' 0. 6.5 6. 3.5 12. 1.5 13.5 0. 15.5 0. 17. 1.5 23. 3.5 29. 6.5
'r30' 0. 2880. 0.0282 0.000014 8 0.050 0.035 0.050 110. 120.
'r34' 0. 17. 10. 12. 110. 2. 111. 0. 119. 0. 120. 2. 220. 12. 230. 17.
'r40' 68. 949. 19.80 1.
'r45' 15.2 24.
'r21' 10 20801 1 0 'miller creek'
'r30' 0. 6360. 0.0316 0.000014 6 0.050 0.050 0.050 20. 34.
'r34' 0. 4. 20. 2. 22. 0. 32. 0. 34. 2. 54. 4.
'r40' 63. 2428. 22.72 2.
'r45' 16.5 24.
'r21' 11 20901 3 0 'arroyo san pablo'
'r30' 0. 8280. 0.0424 0.000014 4 0.0 0.050 0.0 0. 91.
'r34' 0. 5.5 5.5 0. 85.5 0. 91. 5.5
'r30' 0. 5520. 0.0136 0.000014 4 0.0 0.050 0.0 0. 72.
'r34' 0. 8. 56. 0. 64. 0. 72. 8.
'r30' 0. 2400. 0.0083 0.000014 4 0.0 0.050 0.0 0. 35.
'r34' 0. 5. 10. 0. 20. 0. 35. 5.
'r40' 82. 5983. 22.51 1.5
'r45' 14.2 24.
'r21' 12 30101 1 0 'kitchen creek 1'
'r30' 0. 3120. 0.0498 0.000014 6 0.060 0.060 0.060 20. 44.
'r34' 0. 6. 20. 4. 28. 0. 36. 0. 44. 4. 64. 6.
'r40' 76. 441. 37.33 1.
'r45' 30.5 24.
'r21' 13 30102 2 0 'kitchen creek 2'
'r30' 0. 3960. 0.0381 0.000014 8 0.060 0.040 0.060 47.5 54.5
'r34' 0. 16.75 45. 1.75 47.5 1.5 49. 0. 53. 0. 54.5 1.5 57. 1.75 102. 16.75
'r30' 0. 3960. 0.0381 0.000014 8 0.060 0.070 0.060 55. 79.
'r34' 0. 12.5 10. 7.5 55. 3. 58. 0. 73. 0. 79. 3. 94. 4.5 104. 9.5
'r40' 75. 2503. 39.64 2.
'r45' 30.5 24.
'r21' 14 30201 1 0 'la posta creek 1'
'r30' 0. 14160. 0.0357 0.000014 4 0. 0.04 0. 0. 27.
'r34' 0. 6. 12. 0. 15. 0. 27. 6.
'r40' 73. 2819. 31.80 2.
'r45' 25.4 24.
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'r21' 15 30202 3 0 'la posta creek 2'
'r30' 0. 4640. 0.0101 0.000014 6 0.060 0.060 0.060 20. 46.
'r34' 0. 5. 20. 3. 23. 0. 43. 0. 46. 3. 66. 5.
'r30' 0. 4640. 0.0101 0.000014 4 0.0 0.060 0.0 0. 35.
'r34' 0. 5. 10. 0. 25. 0. 35. 5.
'r30' 0. 4640. 0.0101 0.000014 6 0.060 0.045 0.060 20. 27.
'r34' 0. 5. 20. 3. 23. 0. 24. 0. 27. 3. 47. 5.
'r40' 64. 6447. 24.48 2.
'r45' 24.1 24.
'r21' 16 30301 1 0 'morena creek'
'r30' 0. 4920. 0.0458 0.000014 8 0.070 0.030 0.070 16. 20.
'r34' 0. 5.3 3. 2.3 16. 1. 17. 0. 19. 0. 20. 1. 33. 2.3 36. 5.3
'r40' 73. 2025. 27.68 2.
'r45' 21.6 24.
'r21' 17 30401 1 0 'morena virtual'
'r30' 0. 4920. 0.0458 0.000014 8 0.070 0.030 0.070 16. 20.
'r34' 0. 5.3 3. 2.3 16. 1. 17. 0. 19. 0. 20. 1. 33. 2.3 36. 5.3
'r40' 73. 1000. 30. 1.
'r45' 0. 24.
'r21' 18 30501 1 0 'hauser creek'
'r30' 0. 3600. 0.0618 0.000014 6 0.060 0.050 0.060 21. 30.
'r34' 0. 5. 21. 2. 23. 0. 28. 0. 30. 2. 51. 5.
'r40' 62. 857. 35.56 1.
'r45' 17.8 24.
'r21' 19 30601 1 0 'pine valley creek 1'
'r30' 0. 6480. 0.031 0.000014 8 0.100 0.050 0.100 25. 35.
'r34' 0. 8.5 5. 3.5 25. 1.5 28. 0. 32. 0. 35. 1.5 55. 3.5 60. 8.5
'r40' 78. 1305. 37.70 1.
'r45' 30.5 24.
'r21' 20 30602 4 0 'pine valley creek 2'
'r30' 0. 1360. 0.0104 0.000014 8 0.100 0.050 0.100 25. 35.
'r34' 0. 8.5 5. 3.5 25. 1.5 28. 0. 32. 0. 35. 1.5 55. 3.5 60. 8.5
'r30' 0. 1360. 0.0104 0.000014 8 0.070 0.030 0.040 13. 29.5
'r34' 0. 9. 5. 4. 13. 2. 16.75 0. 25.75 0. 29.75 2. 49.5 4. 54.5 9.
'r30' 0. 1360. 0.0104 0.000014 8 0.050 0.030 0.050 35. 48.
'r34' 0. 23.5 20. 3.5 35. 2. 39. 0. 44. 0. 48. 2. 53. 2.5 73. 22.5
'r30' 0. 10320. 0.0295 0.000014 4 0. 0.050 0. 0. 66.
'r34' 0. 20. 30. 0. 36. 0. 66. 20.
'r40' 71. 6924. 28.00 2.
'r45' 25.4 24.
'r21' 21 30603 1 0 'pine valley creek 3'
'r30' 0. 9840. 0.0211 0.000014 4 0.0 0.050 0.0 0. 48.
'r34' 0. 20. 20. 0. 28. 0. 48. 20.
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'r40' 81. 2128. 40.62 2.
'r45' 20.3 24.
'r21' 22 -30604 1 0 'pine valley creek 4 null'
'r21' 23 30605 1 0 'pine valley creek 5'
'r30' 0. 5040. 0.0194 0.000014 4 0.0 0.050 0.0 0. 50.
'r34' 0. 20. 20. 0. 30. 0. 50. 20.
'r40' 73. 741. 43.36 1.
'r45' 20.3 24.
'r21' 24 30701 1 0 'corral canyon'
'r30' 0. 5760. 0.0644 0.000014 6 0.060 0.050 0.060 30. 43.
'r34' 0. 10. 30. 5. 35. 0. 39. 0. 43. 5. 73. 10.
'r40' 68. 1377. 26.98 1.
'r45' 21.6 24.
'r21' 25 30801 1 0 'wilson creek'
'r30' 0. 2400. 0.0279 0.000014 4 0.00 0.05 0.00 0. 26.
'r34' 0. 10. 10. 0. 16. 0. 26. 10.
'r40' 77. 875. 35.53 1.
'r45' 16.5 24.
'r21' 26 30901 1 0 'barrett lake virtual'
'r30' 0. 2400. 0.0279 0. 4 0.00 0.05 0.00 0. 26.
'r34' 0. 10. 10. 0. 16. 0. 26. 10.
'r40' 73. 1000. 30. 1.
'r45' 0. 24.
'r21' 27 31001 1 0 'rattlesnake canyon'
'r30' 0. 3360. 0.1270 0.000014 8 0.075 0.075 0.075 25. 41.
'r34' 0. 10. 5. 5. 25. 3. 31. 0. 35. 0. 41. 3. 61. 5. 66. 10.
'r40' 81. 287. 48.91 1.
'r45' 16.5 24.
'r21' 28 31101 1 0 'mcalmond canyon'
'r30' 0. 6480. 0.0602 0.000014 4 0.0 0.060 0.0 0. 30.
'r34' 0. 5. 10. 0. 20. 0. 30. 5.
'r40' 84. 1155. 38.45 1.
'r45' 16.5 24.
'r21' 29 31201 1 0 'potrero creek'
'r30' 0. 12720. 0.0367 0.000014 4 0.0 0.075 0.0 0. 20.
'r34' 0. 5. 10. 0. 15. 0. 20. 5.
'r40' 76. 4394. 25.54 2.
'r45' 17.8 24.
'r21' 30 31301 1 0 'bee canyon'
'r30' 0. 2640. 0.0623 0.000014 6 0.075 0.050 0.075 25. 35.
'r34' 0. 4.5 25. 2. 27. 0. 33. 0. 35. 2. 60. 4.5
'r40' 82. 478. 38.34 1.
'r45' 16.5 24.
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'r21' 31 31401 2 0 'campo creek 1'
'r30' 0. 4872. 0.0263 0.000014 6 0.040 0.050 0.060 20. 34.
'r34' 0. 6. 20. 4. 24. 0. 30. 0. 34. 4. 54. 6.
'r30' 0. 2088. 0.0263 0.000014 6 0.060 0.040 0.060 8. 23.
'r34' 0. 4. 8. 2. 14. 0. 17. 0. 23. 2. 31. 4.
'r40' 56. 2146. 10.71 2.
'r45' 14.0 24.
'r21' 32 31402 1 0 'campo creek 2'
'r30' 0. 4080. 0.0284 0.000014 4 0. 0.06 0. 0. 42.
'r34' 0. 15. 15. 0. 27. 0. 42. 15.
'r40' 65. 2167. 16.94 2.
'r45' 13.7 24.
'r21' 33 31403 3 0 'campo-tecate'
'r30' 0. 7200. 0.0134 0.000014 6 0.030 0.050 0.030 50. 74.
'r34' 0. 13. 50. 8. 52. 0. 72. 0. 74. 8. 124. 13.
'r30' 0. 7200. 0.0134 0.000014 8 0.030 0.070 0.030 20. 43.
'r34' 0. 11.5 5. 6.5 20. 5. 30. 0. 33. 0. 43. 5. 58. 6.5 63. 11.5
'r30' 0. 7200. 0.0134 0.000014 6 0.030 0.060 0.030 30. 47.
'r34' 0. 9. 30. 6. 36. 0. 41. 0. 47. 6. 77. 9.
'r40' 69. 13263. 20.25 2.
'r45' 15.7 24.
'r21' 34 31404 3 0 'arroyo tecate'
'r30' 0. 6540. 0.0153 0.000014 8 0.050 0.035 0.050 24. 42.5
'r34' 0. 7. 20. 5. 24. 3. 24.75 0. 40.75 0. 42.25 3. 46.25 5. 66.25 7.
'r30' 0. 6540. 0.0153 0.000014 6 0.050 0.035 0.050 20. 50.
'r34' 0. 7. 20. 7. 27.5 0. 42.5 0. 50. 5. 70. 7.
'r30' 0. 13080. 0.0153 0.000014 6 0.060 0.030 0.000 35. 49.
'r34' 0. 8.5 5. 3.5 35. 0.5 35.5 0. 39. 0. 49. 10.
'r40' 84. 8890. 28.13 2.
'r45' 17.3 24.
'r21' 35 31501 1 0 'mine canyon'
'r30' 0. 4800 0.0546 0.000014 6 0.075 0.050 0.075 25. 37.
'r34' 0. 4.5 25. 2. 27. 0. 35. 0. 37. 2. 62. 4.5
'r40' 85. 790. 40.73 1.
'r45' 16.5 24.
'r21' 36 31601 1 0 'alamar virtual'
'r30' 0. 9840. 0.0242 0. 6 0.060 0.040 0.060 20. 40.
'r34' 0. 6. 20. 4. 28. 0. 32. 0. 40. 4. 60. 6.
'r40' 73. 1000. 30. 1.
'r45' 0. 24.
'r21' 37 40101 1 0 'cottonwood creek 01'
'r30' 0. 9840. 0.0242 0.000014 6 0.060 0.040 0.060 20. 40.
'r34' 0. 6. 20. 4. 28. 0. 32. 0. 40. 4. 60. 6.
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'r40' 74. 2950. 26.97 2.
'r45' 27.9 24.
'r21' 38 40102 1 0 'cottonwood creek 02'
'r30' 0. 2400. 0.0039 0.000014 8 0.070 0.030 0.070 75. 79.
'r34' 0. 12. 20. 2. 75. 0.5 75.5 0. 78.5 0. 79. 0.5 134. 2. 154. 12.
'r40' 72. 948. 20.17 1.
'r45' 22.9 24.
'r21' 39 -40103 1 0 'cottonwood creek 03 null'
'r21' 40 40104 1 1 'morena reservoir'
'r32' 30 915.894
'r36'
914.400 14481076. 0.00
915.314 16405308. 0.00
916.229 18563902. 0.00
917.143 20981526. 0.00
918.058 23658182. 0.00
918.972 26630872. 0.00
919.886 29899600. 0.00
920.801 33489032. 0.00
921.715 37349828. 0.00
922.630 41481992. 0.00
923.544 45885524. 0.00
924.458 50622092. 0.00
925.373 55704040. 0.00
926.287 61168364. 0.00
926.409 61928188. 0.00
926.592 63067924. 13.76
926.897 65004492. 59.95
927.202 66978064. 124.20
927.506 68988640. 202.32
927.811 71023880. 301.09
928.116 73083800. 404.45
928.421 75180720. 532.70
928.726 77302304. 658.25
929.030 79448560. 814.99
929.335 81631824. 961.19
929.640 83852096. 1146.21
929.945 86097032. 1312.17
930.250 88378968. 1525.60
930.554 90685584. 1710.79
930.676 91647696. 1786.82
'r40' 70. 3005. 19.92 1.2
'r45' 19.1 24.
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```
'r21' 41 40105 1 0 'cottonwood creek 05'
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'r45' 17.8 24.
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Table 10. Flood Discharges (m^3 s^{-1}) Calculated for Cottonwood Creek - Arroyo Alamar by Rainfall Runoff Modeling

Location/Return period (years)	2	5	10	25	50
1. Upstream of Morena Dam	309	536	663	913	1069
2. Downstream of Morena Dam	34	49	82	129	162
3. Usptream of Barrett Dam	274	446	596	795	941
4. Downstream of Barrett Dam	36	70	84	140	180
5. Usptream of project reach	245	484	620	859	1058
6. Downstream of project reach	277	529	683	928	1135
7. Contribution of reach 40117	32	45	63	69	77
8. Adopted design discharge	280	530	680	930	1140

Location/Return period (years)	100	200	500	1000
1. Upstream of Morena Dam	1294	1413	1633	1799
2. Downstream of Morena Dam	207	230	277	314
3. Usptream of Barrett Dam	1120	1218	1387	1509
4. Downstream of Barrett Dam	220	321	501	635
5. Usptream of project reach	1227	1330	1503	1623
6. Downstream of project reach	1308	1417	1596	1722
7. Contribution of reach 40117	81	87	93	99
8. Adopted design discharge	1310	1420	1600	1720

Table 11. Design Flood Hydrographs for the Channelization Project

Upstream of the project	Downstream of the project
2-yr frequency	2-yr frequency
5-yr frequency	5-yr frequency
10-yr frequency	10-yr frequency
25-yr frequency	25-yr frequency
50-yr frequency	50-yr frequency
100-yr frequency	100-yr frequency
200-yr frequency	200-yr frequency
500-yr frequency	500-yr frequency
1000-yr frequency	1000-yr frequency

Table 12. Flood Discharges ($m^3 s^{-1}$) Calculated for Arroyo Alamar With and Without Infiltration in the Channelization Project Reach (40117)

Return period (years)	2	5	10	25	50
1. Discharge without infiltration (m^3s^{-1})	283	537	692	938	1146
2. Discharge with infiltration (m^3s^{-1})	277	529	683	928	1135
3. Difference (m^3s^{-1})	6	8	9	10	11
4. Runoff volume without infiltration (hm^3)	9.982	20.291	27.279	40.338	52.007
5. Runoff volume with infiltration (hm^3)	9.523	19.692	26.613	39.545	51.087
6. Difference in runoff volume (hm^3)	0.459	0.599	0.657	0.793	0.92
7. Percentage [(6/4)x100]	4.6	2.95	2.41	1.97	1.77

Return period (years)	100	200	500	1000
1. Discharge without infiltration (m^3s^{-1})	1319	1429	1609	1735
2. Discharge with infiltration (m^3s^{-1})	1308	1417	1596	1722
3. Difference (m^3s^{-1})	11	12	13	13
4. Runoff volume without infiltration (hm^3)	70.083	83.003	106.51	127.793
5. Runoff volume with infiltration (hm^3)	68.972	81.805	104.68	125.709
6. Difference in runoff volume (hm^3)	1.111	1.198	1.83	2.084
7. Percentage [(6/4)x100]	1.59	1.44	1.72	1.63