FINAL REPORT

BROADMOOR RESORT COMMUNITY SOUTH MASTER DEVELOPMENT DRAINAGE PLAN

Prepared for:
Broadmoor Resort Community
10 Lake Circle
Colorado Springs, Colorado 80906

March 13, 1998

Woodward-Clyde

Woodward-Clyde International-Americas
Stanford Place Three, Suite 1000
4582 South Ulster Street
Denver, Colorado 80237

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December 19, 1997
Revised: March 13, 1998

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Stanford Place 3, Suite 1000
4582 South Ulster Street
Denver, CO 80237

Project 24389

Broadmoor Resort Community
South Master Development Drainage Plan

Engineer's Statement:

The attached drainage plan and report were prepared under my direction and supervision and are correct to the best of my knowledge and belief. Said drainage report has been prepared according to the criteria established by the City/County for master drainage plans. I accept responsibility for any liability caused by any negligent acts, errors or omissions on my part in preparing this report.

3/13/98
Stephen W. Rogers, P.E.

STEPHEN W. ROGERS
28368

Developer's Statement:

I, the developer, have read and will comply with all of the requirements specified in this drainage report and plan.

Broadmoor Resort Community

By:

Title: Director of Development

Address: 10 Lake Circle
Colorado Springs, CO 80906

City of Colorado Springs

Filed in accordance with Section 15-3-906 of the code of the City of Colorado Springs, 1980, as amended.

City Engineer

4/2/98
Date

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The Broadmoor Resort Community property is located on a series of old coalescing alluvial fans located at the eastern toe of Cheyenne Mountain west of Colorado Springs, Colorado. As recently as 1965, significant floods generated from strong, convective thunderstorms, have occurred in the vicinity of Ski Hill and Fishers Canyon areas, which have been documented to have conveyed mud and debris downstream from the upper watersheds.

Residential development has occurred on the old alluvial fan surfaces below the steep canyons on the eastern slope of Cheyenne Mountain. The scenic beauty and raised elevations are desirable for residential development and, as such, The Broadmoor Resort Community is planning for continued phased development. However, alluvial fans typically display characteristics whereby conveyance channels are neither well-defined nor stable.

Based on the presence of numerous old trees on the fan surface, it is believed that the alluvial surfaces at the base of Cheyenne Mountain are somewhat stable but, a large infrequent precipitation event and the associated runoff could cause channel instability. Engineering controls, as recommended herein, will minimize the potential for channel instability on the downstream fan surfaces.

This Master Development Drainage Plan (MDDP) has been prepared to identify drainage and conveyance issues associated with the proposed development south of and including Fishers Canyon and is required by the City of Colorado Springs for developments within any drainage basin. The purpose of the MDDP is to address major drainage planning for the proposed development before individual phases of development are undertaken. The planning is required so that drainage and hazards associated with flooding can be addressed in the design of the proposed development. This MDDP is compatible with the Neil Ranch MDDP (KLH, 1982) as updated by various drainage plans for individual developments (Watts, 1988; Watts, 1989) and should serve as a guide for future planning and drainage facility design. Numerous reports and references were reviewed as part of the preparation of this report. A list of references reviewed is included in Section 7.0. Site specific hydraulic design will be completed with the individual final drainage plans and reports submitted for platting. Fishers Canyon is a major drainageway as identified by the City/County (has 100-year floodplain designation along selected reaches).

This report will present estimates of off-site peak storm runoff discharges, estimate on-site peak runoff rates, and will make recommendations for major drainage facilities associated with the proposed development. Site specific hydrologic analysis and hydraulic design will be completed concurrently with individual final drainage plans and reports submitted for platting approval.

Previous studies have been reviewed as part of the preparation of this report and have been utilized to the extent possible to maintain consistency. These studies reviewed are included in the references section of this report.

Previous analysis have identified debris flows or hyperconcentrated sediment flows to be a major design issue for drainage and conveyance facilities. This report will address the debris flow issues and make recommendations for drainage/conveyance facility design.

2.1 GENERAL LOCATION AND DESCRIPTION

The Broadmoor Residential Resort Community South is located in the southwestern corner of the City of Colorado Springs in portions of Sections 11, 12, 13 and 14 of Township 15 South, Range 67 West of the 6th Prime Meridian. The watersheds affecting this property extend into Sections 10 and 15 of Township 15 South, Range 67 West of the 6th Prime Meridian. Figure 1 presents a vicinity map of the area. The proposed development is bordered on the west by unplatted Broadmoor Property, to the south by U.S. Government property (NORAD), and to the north by the Broadmoor Residential Resort Community North. Portions of the proposed development are bordered on the east by Langdale Way, Star Ranch and the Boulders Broadmoor development. In general, development on the proposed property is currently limited to below Elevation 6900 feet due to water distribution constraints.

All of the watershed drainages studied are tributary to Fountain Creek. Fountain Creek is a major tributary to the Arkansas River which travels south through the City of Colorado Springs.

2.2 PROPOSED DEVELOPMENT

The Broadmoor Residential Resort Community development is zoned as a Planned Urban Development (PUD) and will consist of single family residential structures, multiple family condominiums. The proposed development will encompass approximately 235 acres south of the Broadmoor Residential Resort Community North line and north of the southernmost property line. Part of this development is currently under preliminary construction. The proposed residential lots range from 1/4 acre to 5 acres in size. The general plan of the proposed development is provided in Exhibit A. A large portion of the property (essentially the property area above elevation 6900 feet) is currently planned to remain undeveloped. All streets and drainage improvements located within the Broadmoor Residential Resort Community will be private and will be owned and maintained by the Broadmoor Resort Community Home Owner's Association.

In order to adequately identify and delineate hazards associated with extreme flood and debris flow events and determine design flow rates for conveyance facility design, an estimation of the design flood magnitude must be developed. This can be performed based on statistical flood frequency analysis of gauged stream flows or by estimation of the design rainfall event in conjunction with flood simulation via a rainfall-runoff model. Where stream gage records are limited or unavailable, regression equations may be applied to the analysis in order to supplement the lack of available data.

Review of available information indicates that there are no stream gages in or adjacent to the Broadmoor Resort Community watersheds. A hydrologic analysis for all off-site basins within the Broadmoor Resort Community was performed by FLO Engineering in 1995 (FLO Engineering, 1995) as part of the North Master Development Drainage Plan (FLO Engineering, 1997) and was reviewed and approved by the City of Colorado Springs Engineering Division. This hydrologic analysis was reviewed as part of the preparation of this Master Drainage Plan. Review of the analysis indicated that the off-site flows at the canyon apexes are adequate for use in further analysis discussed herein. The FLO Engineering Design Flood Hydrology Report is presented in Appendix A.

Additional hydrologic analysis were performed utilizing the HEC-1 (USACOE, 1990) computer model for both the off-site and on-site watersheds for both the existing and proposed conditions.

Results of the HEC-1 computer model are included in Appendix B and further hydrologic and hydraulic computations are included in Appendix C.

3.1 DRAINAGE BASIN DESCRIPTION

The following section describes the existing hydrologic characteristics of the drainage basins related to the proposed development. The hydrologic characteristics evaluated include soils, precipitation and major drainages and channels. Figure 2 presents a general plan of the drainage basin affecting the proposed development.

Soils

The Broadmoor Residential Community property soils can be described as loamy with some significant percentages of clay in some locations. The development area soils have been described in previous reports (KLH, 1982; Weiss, 1987; RCI, 1989; Muller, 1991; FLO Engineering, 1997). Rock outcrops are prevalent in the canyon drainages of Cheyenne Mountain. Along the base of Cheyenne Mountain, coalescing alluvial fans have created non-homogeneous soil groups. The majority of soils in the areas to be developed consist of the Bresser and Jarre-Tecolate Complex which are typically deep and well-drained. The clayey soils in the eastern portion of the property consist of Razor and Razor-Midway complex. Other soils found in the vicinity of the proposed development include the Coldcreek-Tolman complex which consists of a mix of shallow to deep, well-drained soils.

Precipitation

Based on precipitation records for the Broadmoor Mountain Golf Course from 1932-1997, the average annual precipitation in the area is approximately 20 inches. The City of Colorado Springs Drainage Criteria Manual (City of Colorado Springs, 1994) suggests utilizing rainfall depths determined from National Oceanic and Atmospheric Administration (NOAA), a branch of the National Weather Service, for design purposes.

Existing Drainages and Channels

Several existing drainages and channels convey flow across the proposed development. The largest of these is Fishers Canyon. The Fishers Canyon flow path has changed within the last 100 years possibly as recently as 1965. This is evidenced by numerous old channel scars which exist on the fan surface and have apparent small drainage areas. This movement of a drainage channel is typical of an active alluvial fan and is an indication of potential debris flow or hyperconcentrated sediment flow. The existing drainage basins are presented in Exhibit B.

Previous analyses assumed Fishers Canyon flows were conveyed north of Star Ranch. Current conditions indicate that existing flow paths are generally south of Star Ranch. Therefore, without any improvements or development, Fishers Canyon flows would be conveyed south of Star Ranch through the Boulders Broadmoor development. Existing flow paths from the upper watersheds were confirmed by recently flown aerial photography and topographic maps.

3.2 DESIGN CRITERIA

The following discussion relates to the design criteria selected for use in determining peak runoff flow rates. Table 1 provides a summary of the hydrologic characteristics for each drainage basin evaluated. In general, the criteria outlined in the City of Colorado Springs and El Paso County Drainage Criteria Manual (City of Colorado Springs, 1994) was utilized in determining drainage basin characteristics.

Precipitation

The 100-year return period, 2-hour duration design storm of 3.10 inches was utilized for determining peak design discharges for this study. The 2-hour duration precipitation event was determined to produce the highest peak runoff rates within the upper watersheds (FLO Engineering, 1995). The design storm of 3.10 inches is consistent with available 24-hour precipitation records available for the Mountain Golf Course.

During the last five years, the area has experienced several large extreme precipitation events. On May 29, 1995, the Mountain Golf Course precipitation gage recorded a maximum 24-hour precipitation depth of 4.30 inches. In 1994, the maximum recorded 24-hour precipitation depth at the Mountain Golf Course was 3.5 inches. Assuming a standard SCS Type II precipitation distribution, the most intense 2-hour increment of the design storm would receive on the order of 55% of the total 24-hour precipitation depth. This corresponds to an equivalent 2-hour precipitation of approximately 2.37 inches for the May 29, 1995 event. Therefore, a 100-year return period, 2-hour duration design storm of 3.10 inches appears to be reasonable.

Drainage Basin Delineation

The major basins described in previous sections were divided into numerous subbasins for hydrologic modeling purposes. In general, each subbasin represents an area of essentially similar hydrologic characteristics and was identified to determine a design flow rate at a particular point of interest. Drainage basins were determined from available topographic mapping supplemented by a site reconnaissance of the watersheds. Available topography above elevation 7000 feet is limited in accuracy. The drainage basin areas for the major off-site drainages were adopted from previous reports (FLO Engineering, 1995) after reviewing the drainages area for consistency with available data. Major on-site drainage basins are identified as Basins 100, 200, 300, 400 and 500 as shown on Exhibit B.

Infiltration

Infiltration within the drainage basins was simulated utilizing the Natural Resources Conservation Service (formerly the Soil Conservation Service (SCS)) SCS curve number approach. The hydrologic classification of these soils is generally in Hydrologic Soil Group C to D for the upper watersheds and Hydrologic Soil Group B for the lower watersheds. The NRCS suggest a runoff curve numbers for the existing soils in the development to be approximately 58. The weighted average curve numbers utilized in previous studies for the developed condition in the development area generally range from 72 to 78 (KLH, 1982; RCI, 1991). The effects of the development on infiltration were estimated by weighting the curve number based on the percent of development within a given basin or subbasin using an average CN of 72 for the residential areas of the development. A curve number of 72 was estimated assuming an average lot size between 0.25 and 1 acre. A main feature of the development is to minimize disturbance and leave the surrounding areas in their natural state, therefore, minimizing the increase in runoff potential of the development.

Time of Concentration

The time of concentration of a watershed is defined as the time it takes for a particle of water to travel from the most remote point in the watershed to the design point. The time of concentration within the drainage basins evaluated were estimated utilizing the Kirpich method for the upper watersheds and utilizing the SCS travel time for lower watersheds. For developed conditions, the time of concentration as reduced by 10 percent to account for decreased travel times as a result of the developed conditions. Channel routing was utilized were applicable, however, most of the drainages were determined to be too steep for any significant attenuation of flow rates created by channel storage.

3.3 RAINFALL-RUNOFF MODELING

The runoff for the 5-year and 100-year return period precipitation events were simulated using the U.S. Army Corps of Engineers HEC-1 computer program (USACOE, 1990). A rainfall-runoff model was developed incorporating the analysis previously determined for the off-site drainages at the apex of the canyons of the watersheds (FLO Engineering, 1995). The model was developed utilizing the SCS unit hydrograph methodology incorporating SCS runoff curve numbers and time of concentration parameters. The hydrologic parameters were determined for the additional drainage basins as described in the previous section.

Hydrologic Results

Peak runoff rates for the 5-year and 100-year frequency events are provided in Tables 2 and 3, respectively for both the existing and developed conditions. In general, the effects of the development on the peak runoff rates is small. However, for some of the smaller subbasins where development is planned for the majority of the watershed, peak flows may increase as much as 30 percent due to the development. Regional detention basins have been designed to account for this increased volume created as a result of the development. More information regarding the design of the regional detention basins is provided in Section 4.3.

Peak runoff rates for the existing and developed conditions are provided on Exhibits B and C. Exhibit B also provides ultimate developed flow rates at specific design points as determined from previous studies. In general, the flow rates determined herein are considerably less than those previously determined. Review of previous studies indicates that this is due to 1) smaller drainage areas, 2) methodology utilized and 3) lower curve number created by less than projected development rates. Volumes increased from 0.5 acre-feet to 2.9 acre-feet as a result of the proposed developments within the on-site drainage areas.

The proposed debris basin structure at the apex of Fishers Canyon has been designed to attenuate flows up to the 100-year event. As such, flow rates downstream of the structure have been greatly minimized. Further discussion of the design of this structure is included in Appendix D.

The peak 100-year frequency developed flow below Broadmoor Bluffs Drive from SubBasin 300 and 400 is estimated to be approximately 533 cfs with the proposed debris basin/attenuation structure in-place. The Neil Ranch MDDP (KLH, 1982) estimates the 100-year frequency design event to be approximately 704 cfs. Subsequent revisions to the Neil Ranch MDDP (Watts, 1988 and Watts, 1989) indicate the 100-year frequency design flow rates for the historic and developed conditions to be 526 and 498 cfs, respectively just downstream of Broadmoor Bluffs Drive. The estimated historic design flow rate of 526 is within approximately 1 percent of the design flow rate for the developed condition estimated as part of this MDDP.

A comparison of peak discharges determined utilizing the rational method for the watersheds studied indicated peak unit discharge rates much larger than those expected for the proposed development. Previous studies (RCI, 1989; FLO Engineering, 1995) have reported 100-year frequency peak unit discharge rates for watersheds in the Colorado Springs area ranging from 950 to 1,140 cfs/mi^2. Peak 100-year frequency unit discharge rates for the development watersheds range from 950 to 993 cfs/mi^2 at the watershed outlet points of Basins 300, 400 and 500. For Basins 100 and 200, the peak 100-year frequency peak unit discharge rates are 676 and 882 cfs/mi^2, respectively. The lower unit discharge rate is reflective of the proposed development density and the location of the development on the permeable slopes of the Cheyenne Mountain alluvial fan surface.

A discussion of existing and proposed drainage and conveyance facilities is provided in this section.

4.1 EXISTING DRAINAGE FACILITIES

Most of the existing drainage facilities consist of culverts of various types located downstream of the development and off the project site. The drainage plans for the Boulders Broadmoor Filing 1 and 1A which are currently being constructed, indicate drainage conveyance features for Fishers Canyon through the proposed development. This is a result of the current flow path proceeding to the south. Existing drainage facilities are also present along Star Ranch Road. Table 4 lists the existing drainage and conveyance facilities and their estimated capacities.

In general, most downstream existing conveyance facilities were designed to convey larger developed flows than those determined as part of this study. Previous designs assumed that the majority of flows from Fishers Canyon were conveyed north of Star Ranch (Basin 200). Current conditions indicate that Fishers Canyon flows will be conveyed south of Star Ranch (Basin 300).

4.2 PROPOSED FACILITIES

All drainage improvements to the Broadmoor Residential Resort Community South are to be private facilities constructed by the Broadmoor Resort Community and maintained by the Broadmoor Residential Resort Community Home Owners Association. Preliminary construction is currently in progress with the majority of major drainage improvements planned to be constructed in 1998. Detailed design plans for the proposed drainage improvements will be submitted with the Final Drainage Plans and Reports for the different filings of the proposed phased development.

The majority of proposed facilities are required to ensure that existing major drainages through the development are maintained. This can usually be performed by providing drainage easements in conjunction with minor channel improvements or by providing some sort of engineered structures to convey the flow. Because the development is located on an old alluvial fan, upstream channel stability is a potential concern. The proposed drainage facilities generally include flood conveyance structures within major drainage ways, local drainage improvements to convey runoff from overland flow areas to collector and main channels/culverts, and mitigation measures for hyperconcentrated sediment flows (mud and debris flows). Table 5 lists the proposed drainage and conveyance facilities for the development. The proposed facilities, discussed by basin area, are presented below.

Basin 100

Basin 100 discharges through the proposed Broadmoor Resort Community development north of Star Ranch. Drainage paths from the upper portions of Subbasins 100-A and 100-B cross proposed Road A, however, the drainage from this portion of the basin is limited and for the most part will remain undeveloped. As shown on Exhibit B, runoff from the steep canyons of Cheyenne Mountain is not expected in the current condition for Basin 100, and therefore, the potential for a debris flow is expected to be minimal. The proposed facilities adjacent to proposed Road A would include grading of the road to maintain drainage to a catch basin and culvert crossing under the road.

Proposed Road G is proposed to be constructed in existing Drainage 100B. As such, drainage and flood control facilities will be required to convey this flow adjacent to and/or as part of the street improvements.

Drainage from basin 100A would require an easement from adjacent properties between Roads E and G. The natural channel is adequate to convey developed flows from the upstream watershed.

Proposed Road F will require a culvert crossing to convey the design flow from Drainages 100A and 100B which will be combined upstream of the road crossing. The developed 5-year and 100-year flows from the upstream watershed are estimated to be 1 cfs and 24 cfs, respectively. A 30-inch CMP is adequate to convey this design flow. The downstream natural channel would require an easement from the adjacent properties to maintain flow paths within Drainage 100C. The natural channel is adequate to convey the developed flows from the upstream watershed.

The existing 108-inch CMP crossing of Farthing Drive which conveys flows from Basin 100 has an estimated existing capacity of approximately 460 cfs. This is more than adequate to convey the developed 100-year design discharge of approximately 21 cfs.

Basin 200

A berm or improvements to the channel are required upstream of Basin 200 to maintain Fishers Canyon flows to the "south" channel and prevent migration of flows into Basin 200 or the "north" channel during extreme events. These improvements will be designed to convey the peak 100-year design discharge. Other improvements would include maintaining conveyance for drainages 200A and 200C, including possibly providing an inlet for Drainage 200C in Road H.

With the berm or channel improvements to maintain Fishers Canyon flows to the south the potential for a debris flow will be minimal.

The existing culverts at Langdale Way (a 24-inch CMP at Basin 200C and a 30-inch CMP at 200B) are capable of passing the developed 100-year discharges from Basin 200.

Basin 300

A debris control structure at the apex of Fishers Canyon is being designed to eliminate the majority of sediment and debris transported to the canyon apex during the 100-year event and reduce the peak discharge downstream through the attenuation of flood waters (see Appendix D for conceptual design information). As a result, bulking of the water flows downstream of the structure is not expected during the 100-year event and conveyance structures will be designed to convey the peak developed 100-year discharge.

The drainage and conveyance facilities currently being constructed at the Boulders Broadmoor Filing No. 1 and 1A development are capable of passing the peak attenuated developed 100-year water flood from Fishers Canyon of approximately 362 cfs. These facilities were designed to convey runoff from a "split" of Fishers Canyon flow assuming part of the flow would be conveyed to the "north" channel and enter either Star Ranch or Basin 200 including bulking of the water flow created by debris. Current conditions indicate that the majority of flow will be conveyed to the south channel.

The total 100-year discharge bulked for sediment at the extents of Boulders Broadmoor Filing No. 1 and 1-A without the debris control/flood attenuation structure is estimated to be approximately 790 cfs, (Kiowa Engineering, 1997). The proposed structure will reduce the peak 100-year water discharge from Fishers Canyon assuming attenuation and flow conveyed to the south to an estimated peak discharge of 399 cfs.

Drainage easements will be required for the Fishers Canyon channel and will be maintained by providing either easements, channels or conveyance structures for Drainages 9A, 9B and 300B. Drainage 300 is conveyed to an existing 60-inch CMP at both Ellsworth Street and Broadmoor Bluffs Drive. These structures are estimated to have maximum capacities of approximately 366 and 390 cfs, respectively. Therefore, approximately 33 cfs would overtop the Ellsworth Street curb. Excess flow will be conveyed by Ellsworth Street curb and gutter to the sump in Broadmoor Bluffs Drive at the existing 78-inch CMP culvert crossing. No overtopping of Broadmoor Bluffs Drive is expected during the 100-year frequency design event as flood waters will spill into Basin 400B and be conveyed by the 78-inch CMP culvert crossing at Broadmoor Bluffs Drive. The existing 78-inch CMP has adequate capacity to convey peak 100-year discharges from Basin 400 as well as overflow from Basin 300 at Broadmoor Bluffs Drive. The peak developed 100-year frequency design discharge below Broadmoor Bluffs Drive from the combined drainage of Basins 300 and 400 is estimated to be approximately 533 cfs and is within 1 percent of the developed 100-year frequency design flow rate from the Neil Ranch MDDP as most recently updated (Watts, 1988 and Watts, 1989).

Basin 400

Proposed improvements for Basin 400 include maintaining conveyance for Drainages 8A, 7A and 400A. Because this drainage accepts runoff from the steep canyons of Cheyenne Mountain, the potential for a debris flow exists and therefore conveyance facilities will be designed accordingly utilizing a minimum bulking factor of 2.0. The existing structures at Ellsworth Street (60" RCP) and Boulders Broadmoor (78" CMP) are adequate to convey the peak 100-year design discharge.

Basin 500

Proposed improvements for Basin 500 include maintaining conveyance for Drainages 500A, 500C and 500B, designing street conveyance structures to pass potential debris flows and providing a larger culvert (or similar) for Ellsworth Street (if extended). The design of the Ellsworth Street crossing should be performed by the downstream developer. Discussions with the Boulders Broadmoor indicates that the crossing will consist of a 48-inch RCP with a small detention area which is adequate to convey the peak 100-year discharge.

A berm or rechannelization may be required for Drainage 500A at approximately Elevation 6780 feet. The design of these measures will be included in the preliminary and final drainage reports for future development.

Drainage 500C crosses Star Ranch Road via a 24-inch pipe. Drainage 500 is ultimately conveyed to an existing 90-inch CMP riser structure with a 78-inch orifice cutout (insert) at Broadmoor Bluffs Drive. The structure was designed to store approximately 0.93 acre-feet of storage. Upon construction of regional Detention Pond No. 2, the insert is recommended (based on previous studies) to be removed thus reducing temporary storage.

4.3 REGIONAL DETENTION BASINS

Regional Detention Pond No. 1 is located near the southwest corner of the intersection of Highway 115 and Route 83 just south of Broadmoor Bluffs Drive and accepts flows from Basins 100 and 200. Pond No. 1 was designed for a maximum 100-year developed peak inflow of 1080 cfs with an available storage of approximately 27 acre-feet (Drexel Barrell, 1991). This detention pond was designed to accept developed runoff flow rates from a portion of the Broadmoor Resort Community Development. The historic release rate for the 100-year event is approximately 460 cfs.

Regional Detention Pond No. 2 is located at Route 115 and Norad Road and accepts flow from a portion of the Broadmoor Resort Community Development including flows from Fishers Canyon which would enter the "south" channel and Basins 300, 400, and 500. However, the structure was not originally designed to handle runoff from Fishers Canyon. According to design records and discussion with current designers, the proposed Regional Detention Pond No. 2 has been designed to accommodate developed flows from Fishers Canyon. The structure has been designed for a total release rate of 1280 cfs which is comparable to the historic undeveloped 100-year, 24-hour runoff event. The available storage is approximately 43 acre-feet.

The Regional Detention Ponds were designed assuming a developed Curve Number of 68 for the Broadmoor Residential Resort Development, which is consistent with the Curve Numbers utilized in this study.

In order to minimize potential drainage problems associated with the development, adequate design of conveyance structures including addressing the effects of debris flows is required. Potential drainage problems associated with the proposed development include the following:

- flooding associated with the inability of a natural or improved channel to convey upstream runoff
- local flooding associated with the inability of a conveyance structure (i.e., culvert, bridge, etc.) to convey upstream runoff
- local flooding associated with the "clogging" of conveyance structures as a result of debris flows
- structural damage associated with high-velocity water and/or debris flows
- structural damage associated with erosion
- maintenance associated with debris and sediment deposition

The conveyance structures within the development should be designed for the 100-year debris flow and will greatly reduce the above potential hazards. All housing structures should be located above the 100-year water and debris flooding elevation within a channel.

5.1 FLOOD HAZARDS

FEMA Flood Insurance Rate Maps (FIRM) show the study area to be classified as "Other Areas", Flood Hazard Zone X. As such, this area is determined to be outside the limits of the 500-year floodplain. Fishers Canyon was studied in detail as part of the FEMA Flood Insurance Study (FIS), however, the limits of the study appears to extend to just west of Colorado Route 115.

A statistical procedure exists for estimating the flooding hazards on alluvial fans (FEMA 1990). The evaluation is risk based and is primarily utilized for flood insurance purposes. This evaluation may be initiated by regulatory agencies for the proposed development area in the future.

In general, the natural drainages within the development area are deeply incised as a result of active alluvial fan development and are scattered across the fan surface. The flow from the major canyon watersheds have historically migrated across the alluvial fans leaving behind deeply incised channels as the flow paths have shifted over time. However, it appears that most flow paths have stabilized and the fan is relatively inactive as indicated by the numerous old trees on the fan surface. Current topographic conditions indicate large natural channels that appear to be "oversized" compared to the upstream watershed area. Drainage improvements should either maintain stability of the existing natural channels of the upstream canyon watersheds or incorporate drainage improvements assuming that upstream canyon discharges will continue to "jump" or avulse across the downstream fan surface, from a "major" channel to a "minor" one. The drainage path of Fishers Canyon will be improved as part of the debris control structure design in addition to decreasing downstream flow rates. The conceptual design of the structure is outlined in Appendix D.

5.2 DEBRIS FLOW HAZARDS

As recently as 1965, significant floods generated from strong, convective thunderstorms have occurred in the vicinity of the Ski Hill and Fishers Canyon. The 1965 storm generated significant runoff and conveyed mud and debris downstream of the upper watersheds north of the Ski Hill. There was no documentation of debris flow in Fishers Canyon or other drainages to the south from the 1965 flood event, but some minor flows may have occurred. There is a potential for future debris flow where debris flows occurred in 1965 and in adjacent basins, including Fishers Canyon.

The debris flow hazard is associated primarily with 25-year size storms and larger. Estimates of the available sediment within the Fishers Canyon watershed indicate that the available sediment is less than the amount that could be transported during an extreme runoff event (about 10 percent). However, due to the steepness of the watershed and low vegetative cover in the upper portions of the watershed, a large amount of sediment and debris could become available during events larger than the 25-year frequency event and it is prudent to consider that debris flows will not be sediment-limited. Additionally, fire in the watersheds could reduce the vegetative cover and increase the probability of erosion and available sediment. Mitigation measures following fire should be implemented immediately to reduce potential erosion within the watershed and the amount of sediment transported downstream.

The volume of debris transported during a flood is expected to be an average of 25-40 percent of the water volume and the peak debris discharge is estimated to be 45-55 percent of the peak water discharge (O'Brien and Julien 1997). Previous analyses have recommended, for conveyance design purposes, a minimum sediment concentration of 50 percent by volume (FLO Engineering, 1995). This is reasonable and results in a bulking factor of 2.00 for the peak discharge and runoff volume. The bulking factor is given as $BF=1/(1-Cv)$ where Cv is the average sediment concentration by volume. The bulking factor accounts for increased volume attributed to void space formed during particle deposition. A bulking factor of 2.00 is a recommended minimum for conveyance design purposes of the larger drainages within the study area were the potential for a debris flow exists. A bulking factor of 1.20 is recommended for the smaller drainages where the potential for debris flow is minor.

The debris flow hazard can be mitigated by avoidance, conveyance and storage. Avoidance and conveyance can be achieved by designing conveyance structures to adequately pass debris flows, maintaining the stability of debris flow channels and placing structures as high as possible above drainage channels. Debris flow storage can be implemented above the developed area to capture the debris of a design event and mitigate the debris flow hazard associated with that event. Avoidance, conveyance and storage will be implemented as part of the proposed development. Storage for debris for the 100-year Fishers Canyon flood will be provided by the Fishers Canyon debris control structure. In addition, the structure will attenuate flood waters and reduce peak discharges downstream. The structure will store approximately 7 acre-feet of runoff during the 100-year frequency design event. Conceptual design for this structure is presented in Appendix D to this report. The final design will be reviewed and approved by the Dam Safety Branch of the Colorado State Engineer's Office. Additionally, channel modifications will be included to help convey flood water and debris in existing channels, and structures will not be built in flood channels.

This Master Development Drainage Plan provides peak design flow rates through the proposed development and indicates the need for drainage improvements for specific drainages affected by the proposed development. The off-site structures located downstream of the proposed development should be adequate to convey the peak 100-year water rate after development. Detailed design plans for proposed drainage facilities will be presented with the Preliminary and Final Drainage Reports and Plans submitted for platting approval.

A debris control/attenuation structure and channel conveyance improvements are recommended for Fishers Canyon in order to maintain adequate conveyance for debris flows during the design event. The structure will convey flows to the south of Star Ranch through the Boulders Broadmoor development. Flood attenuation provided by the structure will reduce peak discharges downstream. The proposed improvements for the Boulders Broadmoor Filings No. 1 and 1A development will be adequate to convey the 100-year design water flow from Fishers Canyon. Design discharges as estimated herein do not exceed design flow rates published in the MDDP for downstream developments. The other drainages within the study area are much smaller in aerial extent and the probability of these drainages to generate a debris flow during a large, infrequent rainfall event is low. However, conveyance structures in drainages which originate in the steep canyons of Cheyenne Mountain (Basins 400 and 500) should be designed to carry a potential debris flood during the 100-year frequency event. In general, the structures should be designed using a peak bulking factor of 2.00 which corresponds to a peak sediment concentration of 50 percent.

In general, the peak flows determined by this MDDP are less than those previously determined. As such, downstream conveyance structures will be capable of passing the 100-year peak discharges bulked for a potential debris flood.

The following recommendations are made regarding the drainage facilities for the proposed development:

1. A debris control/flood attenuation structure will be constructed at the apex of Fishers Canyon. This watershed is one of the largest on Cheyenne Mountain and the peak discharge rates that would result from an infrequent precipitation event are high. However, this structure will reduce peak discharges downstream and minimize flooding/debris flow hazards.
2. Conveyance structures within Basins 400 and 500 will be designed to convey potential debris flows by utilizing a minimum bulking factor of 2.0.
3. Channel modifications within Basins 300, 400 and 500 are required to maintain stable flow paths upstream of the proposed developments.
4. Where no upstream channel improvements are made, conveyance facilities will be designed for the largest channel discharge within the subbasin assuming a shift in flow path. The recommended minimum size is 60 inch diameter.
5. Regional Detention Pond No. 2 will be designed to accept runoff from Fishers Canyon assuming flow in the "south" channel.

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TABLE 1
SUMMARY OF HYDROLOGIC PARAMETERS

Basin ID	Area (mi^2)	Curve Number		Lag Time		% Impervious
		Existing	Developed	Existing (hours)	Developed (hours)	
34	0.023	74	74	0.125	0.125	7
5	0.042	74	74	0.131	0.131	7
6	0.022	74	74	0.131	0.131	7
7	0.014	74	74	0.107	0.107	7
8-1	0.056	74	74	0.113	0.113	7
8-2	0.016	74	74	0.086	0.086	7
8-3	0.021	74	74	0.202	0.202	7
9	0.085	74	74	0.125	0.125	4
1011-1	0.035	74	74	0.160	0.160	7
1011-2	0.037	74	74	0.160	0.160	7
12-1	0.089	76	76	0.126	0.126	6
12-2	0.028	76	76	0.113	0.113	6
12-3	0.027	76	76	0.145	0.145	6
12-4	0.038	75	75	0.110	0.110	6
12-5	0.081	76	76	0.154	0.154	10
12-6	0.061	76	76	0.129	0.129	10
12-7	0.016	75	75	0.134	0.134	5
12-8	0.023	75	75	0.077	0.077	5
12-9	0.021	75	75	0.112	0.112	4
12-10	0.069	75	75	0.170	0.170	5
12-11	0.041	74	74	0.073	0.073	10
100A	0.048	58	66	0.271	0.138	4
100B	0.022	58	66	0.260	0.132	4
100C	0.035	58	72	0.292	0.150	4
200A	0.035	58	70	0.281	0.144	4
200B	0.017	58	72	0.281	0.144	4
200C	0.051	58	72	0.281	0.144	4
300A	0.049	58	65	0.313	0.162	4
300B	0.026	58	68	0.247	0.126	4
300C	0.06	58	72	0.288	0.150	4
400A	0.02	58	72	0.406	0.210	4
400B	0.01	58	72	0.406	0.210	4
500A	0.036	58	72	0.313	0.162	4
500B	0.009	58	72	0.208	0.108	4
500C	0.015	58	72	0.208	0.108	4

TABLE 2
5-YEAR PEAK DISCHARGE RESULTS

	Developed		Existing	
Basin ID	$Q_{5YR-2HR}$ (cfs)	5 Year$_{\text{Unit Peak Runoff}}$ (cfs/mi^2)	$Q_{5YR-2HR}$ (cfs)	5 Year$_{\text{Unit Peak Runoff}}$ (cfs/mi^2)
Basin 500				
34	5	217	5	217
500C	2	133	1	67
5	9	214	9	214
6	5	227	5	227
500A	5	139	2	56
DP500	23	167	19	138
500B	1	111	1	111
DP501	24	163	20	136
Basin 400				
7	3	250	3	250
8-1	12	214	12	214
8-2	4	250	4	250
8-3	4	190	4	190
DP7A	22	210	22	210
400A	2	100	1	50
DP401	24	192	22	176
400B	1	100	<1	<100
DP402	24	178	22	163
Basin 300				
12-1	22	247	22	247
12-2	7	250	7	250
12-3	6	222	6	222
12-4	9	237	9	237
12-5	23	284	23	284
12-6	18	295	18	295
12-7	3	188	3	188
12-8	5	217	5	217
12-9	4	191	4	191
12-10	13	188	13	188
Fishers Canyon	57	126	--	--
12-11	11	268	11	268
DP6	61	124	109	221
1011-1	7	200	7	200
1011-2	7	189	7	189
DP8	70	124	121	214
300A	3	61	3	61
9	15	176	15	176
300B	2	77	2	77
DP301	84	109	136	177
300C	8	133	3	50
DP302	90	108	137	165
Basin 200				
200A	3	86	2	57
200C	7	137	3	59
DP200	10	116	5	58
200B	2	118	1	59
Basin 100				
100A	4	83	3	63
100B	2	91	1	45
DP101	5	71	4	57
100C	4	114	2	57
DP102	9	86	6	57

TABLE 3
100-YEAR PEAK DISCHARGE RESULTS

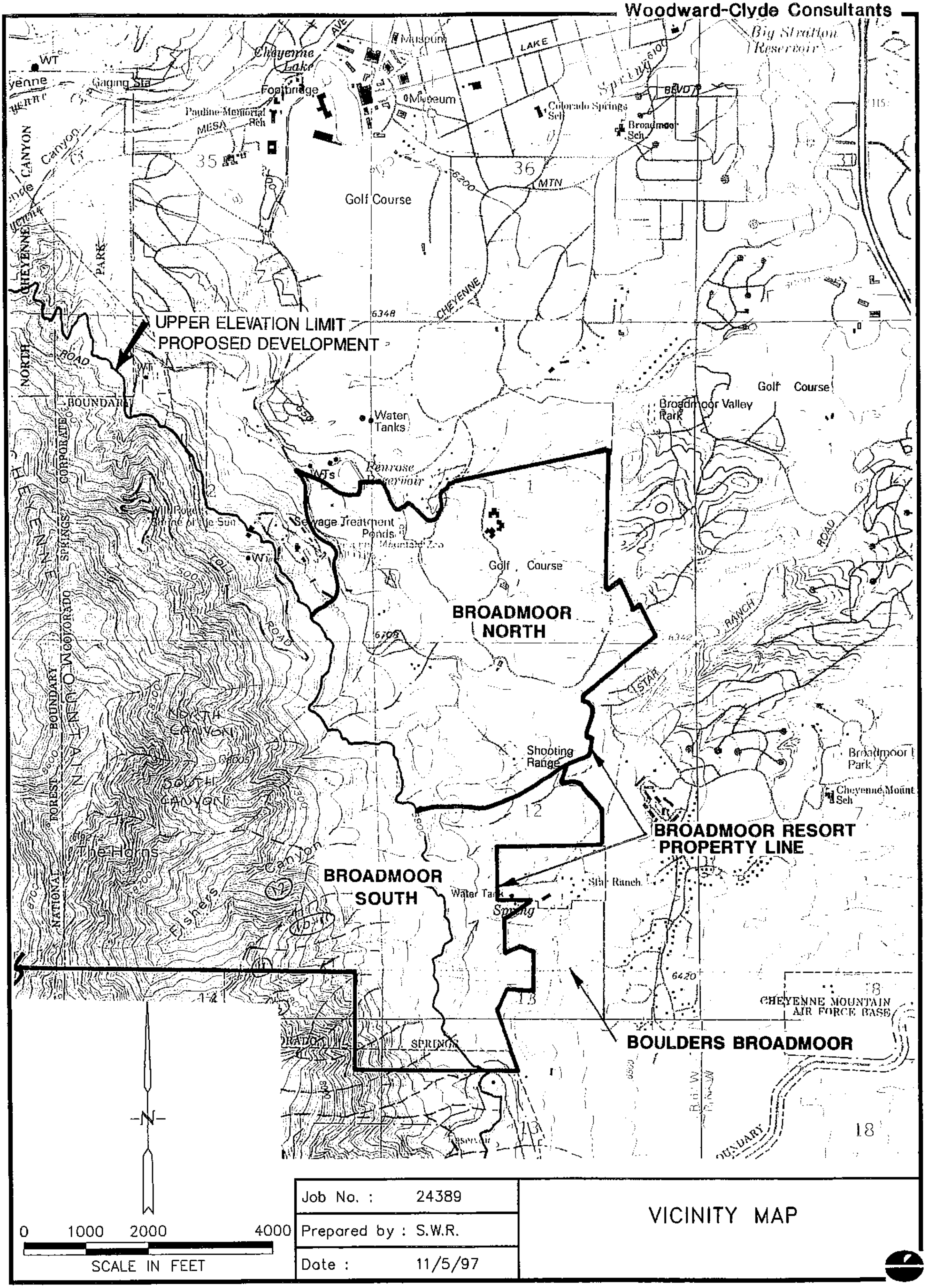
	Developed			Existing		
Basin ID	Q100$_{\text{YR-2HR}}$ (cfs)	V100$_{\text{YR-2HR}}$ (ac-ft)	100 Year$_{\text{Unit Peak Runoff}}$ (cfs/mi^2)	Q100$_{\text{YR-2HR}}$ (cfs)	V100$_{\text{YR-2HR}}$ (ac-ft)	100 Year$_{\text{Unit Peak Runoff}}$ (cfs/mi^2)
Basin 500						
34	26	1.4	1130	26	1.4	1130
500C	15	0.7	1000	4.0	0.2	267
5	47	2.3	1119	47	2.3	1119
6	25	1.2	1136	25	1.2	1136
500A	31	1.7	861	8	0.6	222
DP500	133	7.3	964	98	5.7	710
500B	9	0.5	1000	2	0.2	222
DP501	141	7.8	959	100	5.9	680
Basin 400						
7	17	1.3	1416	17	1.3	1416
8-1	66	2.9	1179	66	2.9	1179
8-2	20	1.1	1250	20	1.1	1250
8-3	20	2.0	952	20	2.0	952
DP7A	117	7.3	1114	117	7.3	1114
400A	16	1.0	800	4	0.4	200
DP401	128	8.3	1024	118	7.7	944
400B	8	0.7	800	2	0.4	200
DP402	134	9.0	993	119	8.1	881
Basin 300						
12-1	112	5.1	1258	112	5.1	1258
12-2	37	1.8	1321	37	1.8	1321
12-3	32	1.8	1185	32	1.8	1185
12-4	47	2.7	1237	47	2.7	1237
12-5	102	5.2	1259	102	5.2	1259
12-6	82	3.4	1344	82	3.4	1344
12-7	18	1.0	1125	18	1.0	1125
12-8	31	1.4	1348	31	1.4	1348
12-9	25	1.6	1190	25	1.6	1190
12-10	72	3.9	1043	72	3.9	1043
Fishers Canyon	222	27.9	490	--	--	--
12-11	57	2.7	1390	57	2.7	1390
DP6	240	23.4	486	564	30.6	1142
1011-1	37	2.1	1057	37	2.1	1057
1011-2	39	2.8	1054	39	2.8	1054
DP8	274	28.3	484	630	35.5	1113
300A	25	1.6	510	11	0.9	224
9	91	4.5	1071	91	1.5	1071
300B	18	1.3	692	6	0.8	231
DP301	362	35.7	471	718	41.7	935
300C	53	2.8	883	14	1.1	233
DP302	399	38.5	481	721	42.8	871
Basin 200						
200A	27	1.5	771	8	0.7	229
200C	45	2.6	882	12	1.1	235
DP200	73	4.1	849	20	1.8	233
200B	15	1.1	882	4	0.6	235
Basin 100						
100A	28	1.6	583	11	0.9	229
100B	13	0.9	591	5	0.6	227
DP101	41	2.5	586	17	1.5	243
100C	31	1.8	886	8	0.8	229
DP102	71	4.3	676	25	2.3	238

TABLE 4
EXISTING DRAINAGE AND CONVEYANCE FACILITIES

Location	Type and Size	Drainage	Approx. Capacity (cfs)	100-year Developed Q (cfs)
Basin 100				
Farthing Drive	108-inch CMP	100C	1130	71
Basin 200				
Langdale Way	24-inch CMP	200C	43	15
Langdale Way	30-inch CMP	200D	73	73
Star Ranch Road	18-inch CMP?	200C	14	15
Farthing Drive	30-inch CMP	200C	62	45
Basin 300				
Jarman Street	2 66-inch RCP	300C (Fishers Canyon)	750	362
Stonebeck Lane (Private Drive)	66-inch RCP	300B	450	362
Ellsworth Street	60-inch CMP	300C	366	399
Broadmoor Bluffs Drive	60-inch CMP	300C	390	399
Basin 400				
Broadmoor Bluffs Drive	78-inch CMP	400B	646	134
Star Ranch Road	18-inch CMP	400A	13	134
Ellsworth Street	60-inch CMP	400A	310	134
Basin 500				
Star Ranch Road	18-inch CMP	500A	14	72
Star Ranch Road	24-inch HDPE	500C	31	41
Star Ranch Road	18-inch CMP	500B	14	9
Ellsworth Street	48-inch RCP	500 A/C	200	133
Broadmoor Bluffs Drive	90-inch CMP w/78-inch orifice	500D	859	141

TABLE 5
PROPOSED DRAINAGE AND CONVEYANCE FACILITIES

Location	Type	Drainage	5-year Discharge (cfs)	100-year Discharge (cfs)	Minimum Capacity (cfs)	Bulking Factor
Basin 100						
Road A	Culvert crossing	100A/100B	1	41	50	1.20
Road G	Storm sewer along road	100B	1	13	16	1.20
Road F	Culvert crossing	100A/100B	1	41	50	1.20
--	Drainage easement	100A	1	28	34	1.20
--	Drainage easement	100C	3	71	85	1.20
Basin 200						
Road H	Culvert crossing	200A	1	27	35	1.20
Road H	Culvert crossing	200C	3	45	55	1.20
Road F/H cul-de-sac	Culvert crossing	200B	1	15	18	1.20
Basin 300						
Berm adj. to Drainage 11B	Earthfill berm/riprap channel	11B	110	270	330	1.20
Berm adj. to Drainage 300B	Earthfill berm/riprap channel	300B	17	91	180	2.00
Fishers Canyon Debris Control Debris Basin/Dam	Debris basin	12	110	564	1120	2.00
--	Drainage easement	300A	121	370	370	1.00
--	Drainage easement	300B	17	109	218	2.00
Basin 400						
--	Drainage easement	400A	20	128	260	2.00
Basin 500						
Ellsworth Street Extension	Culvert crossing	500D	16	133	270	2.00
Berm adj. to Drainage 500A	Earthfill berm/riprap channel		12	72	144	2.00
--	Drainage easement	500A	12	72	144	2.00
--	Drainage easement	500C	4	26	52	2.00

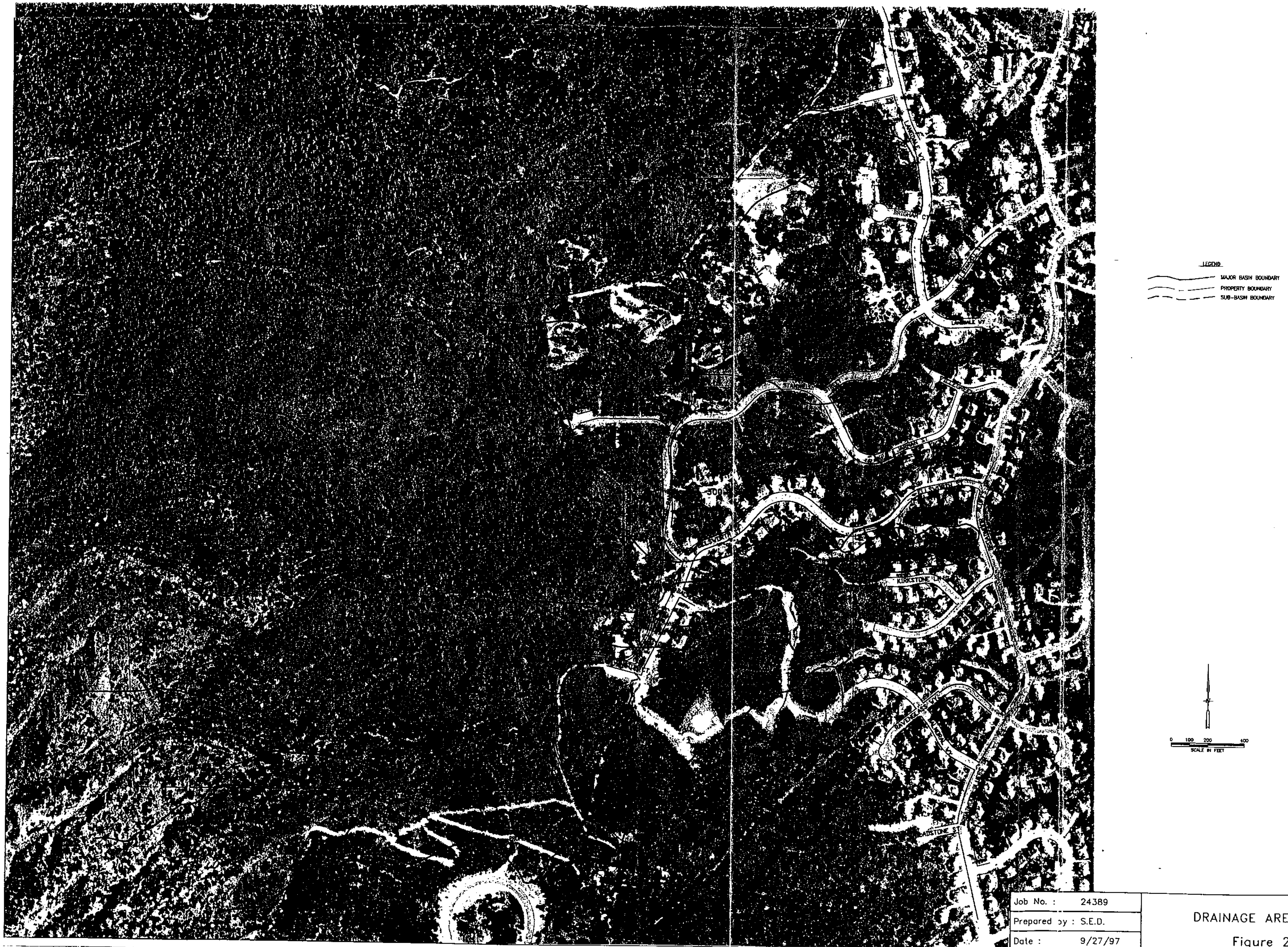


Job No. :	24389
Prepared by :	S.W.R.
Date :	11/5/97

VICINITY MAP

FIG. 1

24389TB



Job No. : 24389
Prepared by : S.E.D.
Date : 9/27/97

DRAINAGE AREA MAP

Figure 2

APPENDIX A FLO Engineering 1995 Design Flood Hydrology Report

CITY ENGINEERING DIVISION
Stormwater and Subdivision

CITY OF COLORADO SPRINGS

February 15, 1995

Dennis Minchow
Rockwell Minchow Consultants
2920 Straus Lane, Suite 100
Colorado Springs CO 80907

BROADMOOR SOUTH HYDROLOGY STUDY

Dear Dennis,

The above referenced hydrology study prepared by FLO Engineering Inc. has been reviewed and a meeting was held on January 30, 1995 with you, Jimmy O'Brien of FLO Engineering, John Maynard and Nolan Shriner of N.E.S., and our staff to discuss the study. We also discussed the use of the *FLO-2D* model.

The engineer examined available rain gauge data in his attempt to select the most appropriate design storm. Upon a frequency analysis of the available data for the 24-hr storm it was determined that the City Criteria 24-hr, 100-yr total rainfall of 4.5 inches is supportable by the data and the assumption was made that the City Criteria 2-hr, 100-yr total rainfall of 3.1 inches is also acceptable. The available data also confirmed the storm distributions per City Criteria for both the 24-hr and the 2-hr storm.

City Criteria requires use of the storm distribution "producing the greatest level protection..." as quoted in the study. The engineer calibrated the hydrologic parameters of the HEC-1 model using gauge data in the adjacent Rock Creek drainage basin. The HEC-1 results for the Broadmoor South basins yield higher peak flows in the 2-hr storm.

Table 6 gives the peak flows for the key design points above the project area. (The flow rates will be bulked to account for mud and debris flow.) These design points are at the apex of the alluvial fans. The developable portion of the site is below these design points on the alluvial fans. No hydrology has been done for the developable site yet.

It is our understanding that once the site layout is determined, the *FLO-2D* model will generate the hydrology for the rest of the site at the same time the mud and debris flows are simulated. We have requested some additional information about how the *FLO-2D* model makes these calculations.

One of the key design issues will be the evaluation of mud/debris flow and requirements for mitigation. To my knowledge we have not addressed this issue on any other development proposals. The *FLO-2D* model will be used to simulate mud/debris flows. This is new to us and we look forward to learning more about it.

This letter will serve as our acceptance of the hydrology report and the apex design point flows.

Sincerely,

David R. Lethbridge
Subdivision Development Specialist

c. Bruce Thorson, Ken Sampley, Robin Kidder, Tim Mitros

101 West Costilla, Suite 122 • TEL 719-578-6212 Stormwater Management/719-578-6208 Subdivision FAX 719-578-6161
Mailing Address: Post Office Box 1575, Mail Code 1110 • Colorado Springs, Colorado 80901-1575

Broadmoor South Property
Design Flood Hydrology

Broadmoor South Master Drainage Plan
FLO Project No. 10522

Prepared For:

Broadmoor Hotel, Inc.
10 Lake Circle
Colorado Springs, CO 80906

Prepared by:

FLO Engineering, Inc.
P.O. Box 1659
Breckenridge, CO 80424
Ph: (303) 453-6394

Revised as Final
December 4, 1995

BROADMOOR SOUTH PROPERTY
DESIGN FLOOD HYDROLOGY

Introduction

The Broadmoor South property is located on a series of coalescing alluvial fans located at the eastern base of Cheyenne Mountain in Colorado Springs, Colorado. In recent history, large magnitude floods in the project vicinity, including those generating mud and debris flows, have been caused by summer convective thunderstorms. Recent mudflow events have occurred from late May to mid-September, but heavy rainfall is also possible in April and October. Mudflows are dependent on the availability of loose sediment and debris in the watershed. Watershed channels may be charged with sediment and produce a mudflow or the channel may be scoured relatively free of sediment from recent storms and create only a water flood. Rainfall that produces mudflow in one basin may not generate a mudflow in a contiguous basin. The frequency of mudflow events for any given watershed is small and if a mudflow event appears in the record, it is usually not representative of the flood populations because the historical record is so short.

Stream Gaging Records

The delineation of flood and debris flow hazards on the property requires the prediction of a design flood event. Large infrequent floods, assigned the status of a design flood event, are commonly determined by a statistical flood frequency analysis of stream gaging station records or by estimating the design rainfall event and simulating the flood with a rainfall-runoff model. The application of regression equations developed from other local or regional stream gages may supplement or replace the analysis of gaging station records if these records are either short or nonexistent.

There are no stream gages in the project watershed. The watersheds are small and very steep, the largest watershed being slightly less than one-half square mile. The nearest stream gage is located on Rock Creek on the southern end of Cheyenne Mountain approximately three miles from the project site. The northern most portion of the Rock Creek watershed is contiguous to the Fisher Canyon basin with the top of Cheyenne Mountain dividing the two basins. The Rock Creek stream gaging station monitors flows for a 6.7 square mile drainage. This drainage is too large to transpose a frequency analysis to the project watersheds, but the stream gaging data can be utilized to calibrate watershed parameters in a rainfall-runoff model.

A review of regression relationships for estimating peak discharges in this region led to the conclusion that application of these equations for the project watersheds was inappropriate. McCain and Jarrett (1976) and Livingston (1981) developed power law regression relationships for peak discharge as a function of basin area. These studies had regressed stream gaging data for Arkansas River gaging stations on the eastern plains. The location of the project site in the foothills of the Rocky Mountains and the relatively small size of the project basins effectively precludes the application of these regression equations for predicting peak flow. Regression relationships for mountain watersheds as presented in McCain and Jarrett (1976) were also determined to be invalid for this area. Regional regression relationships were not used for the prediction of a design flood peak discharge in this investigation.

Rainfall-Runoff Modeling

The Army Corps of Engineers rainfall-runoff simulation model HEC-1 (COE, 1990) was applied to determine flood hydrographs at the watershed mouths for various frequency rainfall events. The HEC-1 model uses as input: rainfall, topographic characteristics of area and slope, soil type, vegetative cover and land use. Channel routing and overland flow are simulated by the model using a kinematic wave representation of the momentum equation.

The 100-year flood constitutes the design flood. To construct the 100-year rainfall event, the rain gage records of five rain stations in the Colorado Springs area were reviewed. In addition, the City of Colorado Springs and El Paso County Drainage Criteria Manual (Drainage Manual) was consulted to determine storm duration and rainfall distribution. The following sections discuss the features of the 100-year storm, watershed parameter calibration and the HEC-1 flood hydrograph simulation.

Precipitation

The Drainage Manual recommends a method to estimate the total rainfall for the 10-yr and 100-yr storms. These total rainfalls are derived from the NOAA Atlas, Volume III. Two storm distributions (for the 2-hr and 24-hr storms) are then applied to construct a potential design storm. The Drainage Manual requires that the "storm distribution producing the greatest level of protection for flood conveyance and storage facilities...," should be used to define the design storm. The 24-hr duration storm was distributed according to the SCS Type IIA storm distribution and the 2-hr storm was distributed on the basis of the Colorado Urban Hydrograph Procedure.

The magnitude of the flood and mud/debris flow hazard is controlled in large measure by the volume and intensity of the rainstorm which is subject to interpretation by the engineer. It is important, therefore, to document the selection of the design storm with supporting data. The rainfall depth and distribution for the project area was analyzed with a data base created with resources available from the National Weather Service and Colorado State University Library.

Available data from local precipitation stations included:

Fort Carson - 1981 to 1990, 10 years of data
Manitou Springs - 1949 to 1986, 38 years of record, missing last few years of data
Fountain - 1954 to 1990, 31 years of record, some missing data
Colorado Springs Airport - 1950 to 1990, 41 years of record
Ruxton Park - 1960 to 1990, 31 years of record

Daily precipitation records were used in this analysis. The maximum historical daily rainfall recorded at the various gages around the project area is presented in Table 1. Four probability distributions were applied to the daily precipitation data: extreme value, log extreme value, log Pearson Type III, and log normal. The applicability of a particular distribution to predict rare rainfall events is a function of the linearity of the plot of the data. The extreme value distribution is the frequency distribution usually applied by the National Weather Service for rainfall analysis. The Water Resources Council (Bulletin 17B, 1981) favors the log Pearson Type III distribution but recognizes that the extreme value distribution is proven to be more appropriate for shorter duration storms such as those used in engineering analyses. Some longer duration rainfalls show tendencies toward the log normal distribution. After a review of the plots of each of these distributions, it was apparent that for the Colorado Springs area the log normal plot produces a more linear relationship and a better predictor of the extreme rainfall events.

Table 1. Historical Maximum 24-hour Rainfall

Station	Maximum Precipitation (inches)
Ft. Carson	2.29" Aug. 8, 1986
Fountain	4.70" June 17, 1965
Manitou Springs	4.75" Oct. 1, 1959
Colorado Springs	3.00" July 22, 1952
Ruxton Park	2.35" April 27, 1967

Table 2 shows the results of the frequency analysis for the 10-year and 100-year, 24 hour storm using the extreme value and log normal distributions.

Table 2 Precipitation Depth Frequency Analysis				
Station or Source (Elev.)	10-Year, 24-hour Precipitation (inches)		100-year, 24-hour Precipitation (inches)	
	Extreme Value	Log Normal	Extreme Value	Log Normal
Fort Carson (5870)	2.43	2.59	3.57	4.07
Fountain (5570)	2.95	2.65	4.78	4.35
Manitou Springs (6630)	3.1	2.92	4.88	4.67
Colorado Springs (6090)	2.46	2.49	3.6	3.7
Ruxton Park (9050)	2.17	2.16	2.97	2.84

The selected total storm rainfall using the Drainage Manual criteria results are presented in Table 3, line 1. The selected rainfall totals in other drainage reports are also presented in Table 3. The results indicate a consistency in the analysis of the design storm criteria.

Table 3. Estimated Storm Total Precipitation Depths				
Source of Data	10-Year Rainfall (inches)		100-year Rainfall (inches)	
	2-Hour Storm	24-Hour Storm	2-Hour Storm	24-Hour Storm
Drainage Manual	2.3	3.2	3.1[1]	4.5
Muller Report	2.1	3.2	3.1	4.5
RCI Report	2.06	3.2	3.05	4.5
Drexel Barrell Report	1.9	2.9	3	4.6

[1] Adjusted for elevation this value would be 2.83 inches

The 24-hour, 100-yr estimated precipitation depths listed in the various reports compare well with the frequency analysis of the daily rainfall data for the Fountain and Manitou Springs gages. The rainfall depths for Ft. Carson and Colorado Springs gages are less than 4.5 inches, only a fair comparison and the Ruxton Park 100-yr, 24-hr predicted depth of 2.84 inches is a poor comparison. The difference between the frequency analysis and the drainage manual 100-year storm depth is related to elevation. The Colorado Springs' airport rain gage is several miles east on the plains and may not reflect the orographic effects of the foothills that the other gages experience. Two of the rain gages have higher maximum rainfalls than the 24-hr, 100-yr predicted rainfall depth of 4.5 inches, but the difference is not significant and it was concluded that these two gages have experienced a 100-yr return period rainstorm.

Based on the frequency analysis, the 4.5 inches total rainfall predicted with the Drainage Manual criteria is a good estimate of the precipitation for the 100-year, 24-hr storm for the Broadmoor South property. Since the Drainage Manual results for the 24 hour storm were supportable, it was assumed that the 2-hr storm also derived from the application of the Drainage Manual criteria would be acceptable. The 2-hr, 100-year rainfall derived from the Drainage Manual by the various studies was approximately 3.1 inches. The Broadmoor South property was higher in average elevation than project areas in the other studies and the adjustment for elevation, according to the Manual, reduced the 2-hr, 100-yr storm from 3.1 inches to 2.83 inches. To conservatively predict runoff, however, 3.1 inches total rainfall was used in the rainfall/runoff simulation.

Rainfall Distribution

The available rainfall gage record was scanned for hourly data to compare with the 2-hour and 24-hour storm distributions recommended by the Drainage Manual. The Drainage Manual requests that both the 2-hr and 24-storm be applied to determine the design storm. The 10-yr and 100-yr, 2-hr storms were plotted in Figure 1 and the 24-hr storm distribution was plotted in Figure 2. The storms with best corresponding distribution found in the historical data were plotted with these prescribed distributions. The most important aspect of the rainfall distribution is the period of most intense rainfall represented by the steepest portion of the duration curve. The period of most intense rainfall fills the potential infiltration with the highest efficiency and generates the most runoff. Several of the 2-hour storms and one of the 24-hour storms have appropriate distributions and intense rainfall periods representative of the prescribed Manual distributions. The actual storm data confirmed the applicability of the Drainage Manual storm distribution criteria for the Colorado Springs area.

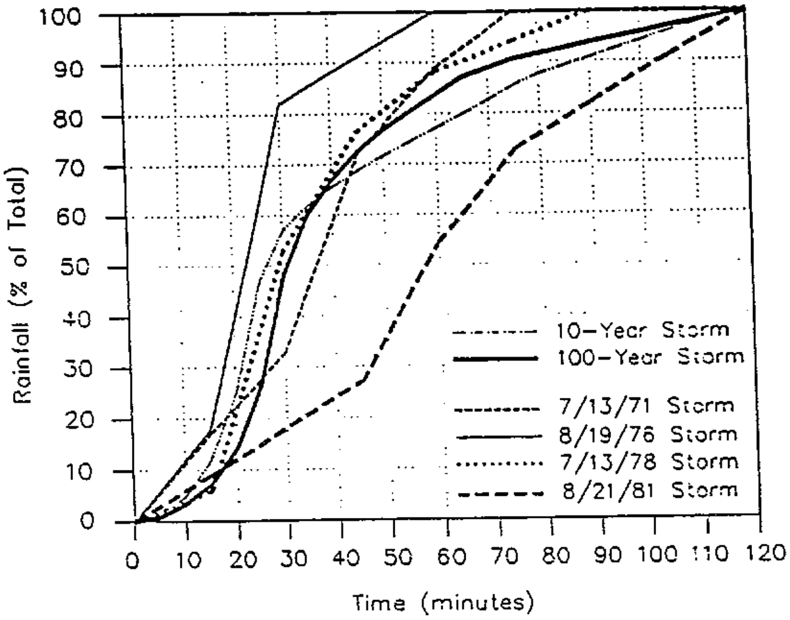


Figure 1. 2-Hour Storm Distributions

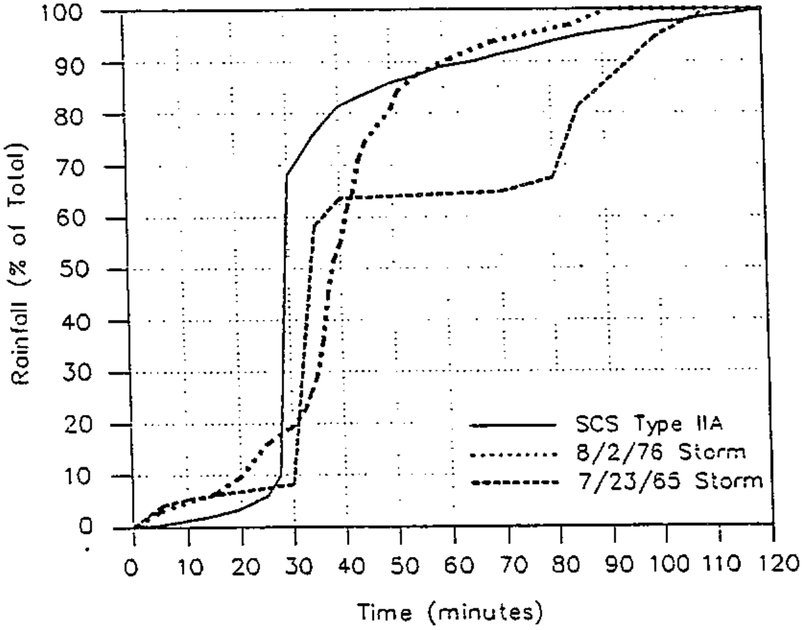


Figure 2. 24-Hour Storm Distributions

HEC-1 Model Calibration

Since the watersheds affecting the Broadmoor South property are small and ungaged, the design storm flood hydrology was predicted with the Corps of Engineers HEC-1 rainfall/runoff model. The application of this watershed model to the project area is appropriate because it is formulated with a kinematic wave approximation to the momentum equation which will accurately simulate flood wave progression on steep slopes (Ponce, et al., 1978). HEC-1 transforms excess rainfall/runoff computed by the SCS curve number method or the Green-Ampt infiltration model into subbasin outflow which is then routed to the watershed mouth as channel flow using the kinematic wave equation.

To estimate HEC-1 hydrologic parameters for the Broadmoor South Property, a nearby gaged watershed was calibrated. The calibrated parameters were then transposed to the study watersheds on the South Broadmoor Property. The final parameters used in the rainfall/runoff simulation were then compared with those applied in other studies in the Colorado Springs area. A brief description of the calibration procedure follows.

Rock Creek is a small watershed to the south of Cheyenne Mountain whose northernmost subbasin extends to the top of Cheyenne Mountain (elev. 9,400 ft). The Rock Creek basin is contiguous to the upper portion the Fisher Canyon watershed (Figure 3). This watershed is gaged near its canyon mouth (elev. 6,400 ft). Most of the basin is vegetated with coniferous trees of the lower Montane ecosystem. The understory is sparsely vegetated. There are numerous exposed outcrops throughout the basin, but the largest outcrops are located in the lower portion of the basin where the channel is confined by vertical canyon walls. Impervious areas were determined based on the percentage of exposed outcrop.

The USGS was consulted in locating Rock Creek gaging records for which there was a corresponding rainfall event recorded in the local rain gage records. Specifically, the Ft. Carson, Fountain, Manitou Springs and Ruxton Park rain gage records were reviewed. The storms producing significant runoff events in Rock Creek were generally local to the watershed and only a few runoff events had a corresponding significant amount of recorded rainfall. Two storms were chosen for the calibration, September 3-4, 1991 and July 19-20, 1985. These were the most recent gaging data with discharge related to summer storm activity. The first storm was used to calibrate the watershed parameters and the second storm was used to verify the accuracy of the parameters.

The Rock Creek discharge data was available in 15 minute increments. The rainfall data for the September, 1991 storm was available in hourly increments for Manitou Springs. The same storm did not rain on the Fountain gage and there was only a minor amount of rain at the Ft. Carson gage. The Mantiou Springs rainfall was assumed to occur on the Rock Creek watershed. It was evident from the stream gaging record that more rainfall fell for a longer duration on the Rock Creek basin than on the Manitou Springs gage because of the protracted period of high flow after the peak discharge passed. For that reason, a calibration was

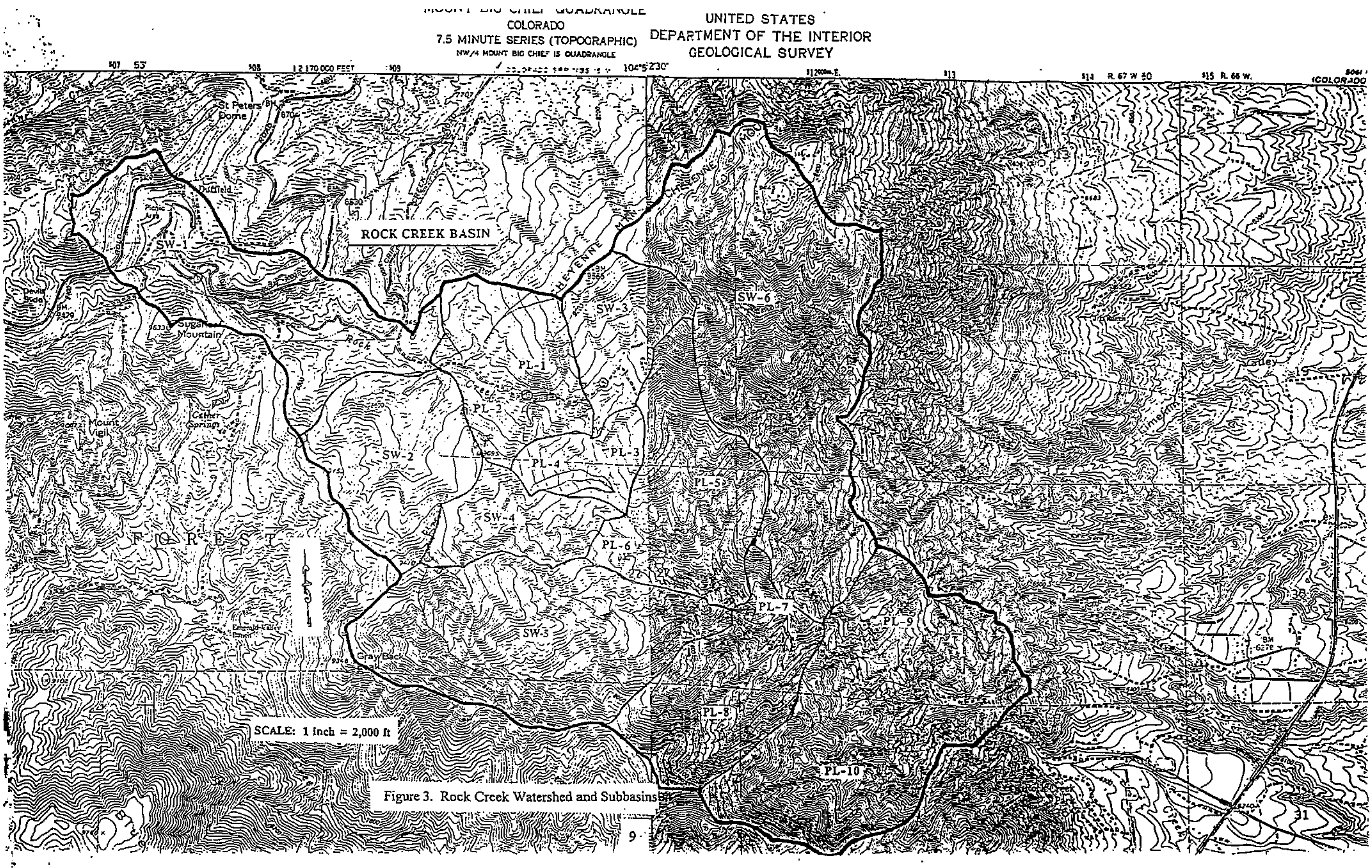


Figure 3. Rock Creek Watershed and Subbasins

performed to match the rising limb and peak discharge and not the volume of the entire hydrograph. A storm distribution roughly approximating the prescribed Drainage Manual criteria for the two-hour rainfall event was assumed and adjusted to help match the timing of the peak. The results of the calibration for the September, 1991 storm are shown in Figure 4 for the SCS curve number and Green-Ampt infiltration methods. The calibrated curve numbers and Green-Ampt infiltration parameters are presented in Table 4.

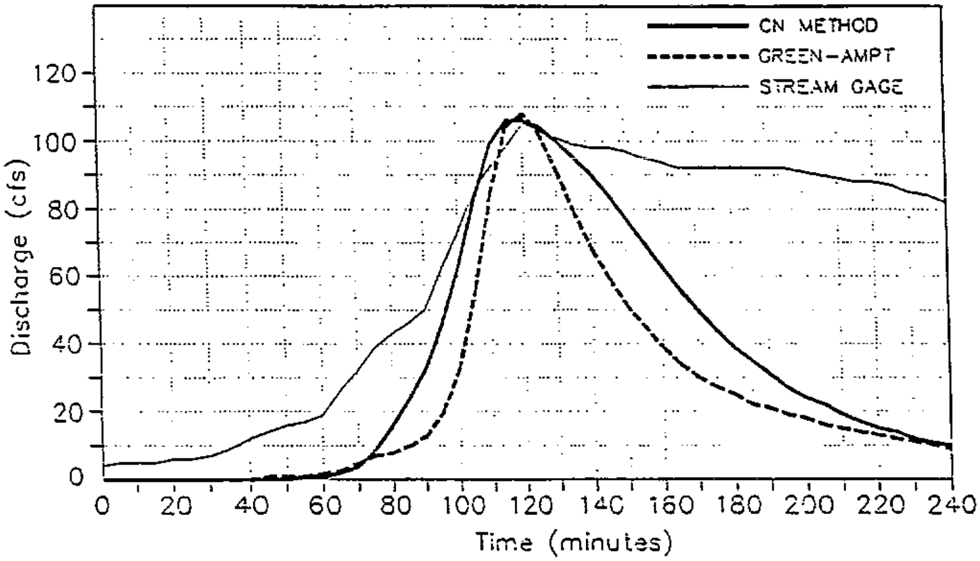


Figure 4. Rock Creek Storm Calibration for the September 3 and 4, 1991 Storm

The July, 1985 rainfall data at the Fountain and Manitou Springs rain gages were very dissimilar. It was noted that Rock Creek is approximately half way between the two gages and therefore the rain gage data were combined to produce a 4-hour, 0.9 inch rainfall on the watershed. Again, the rainfall distribution was adjusted slightly to more closely match the timing of the peak. The rainfall was increased slightly at the outset and was distributed more uniformly on the falling limb of the hydrograph. The assumed storm distribution closely resembled a condensed Type II, 24 hour storm (Figure 5). This second calibration utilized the same curve numbers employed in the initial calibration. Although the discharge was smaller for this storm, the calibration was highly correlated with the measured runoff as shown in Figure 6. No Green-Ampt infiltration parameter calibration was performed on the second storm because the excellent replication was achieved with measured runoff for the first storm using the SCS curve number method.

Table 4: Hydrology Parameters for the Rock Creek Watershed HEC-1 Calibration

Peak Flow = 105 cfs
Volumes[1]: Vol_{CN} = 10.7 ac-ft, Vol_{GA} = 8.2 ac-ft

Basin	Curve Number CN	Initial Loss (in.)	Volume Moisture Deficiency (in.)	Wetting Front Suction (in.)	Hydraulic Conduct. (in.)
SW-1	74	.10	.20	4.15	.46
SW-2	74	.10	.20	4.15	.46
SW-3	75	.10	.20	4.15	.46
SW-4	76	.10	.20	4.15	.46
SW-5	76	.10	.20	4.17	.48
SW-6	75	.10	.20	4.17	.48
PL-12	74	.10	.20	4.17	.48
PL-34	76	.10	.20	4.17	.48
PL-56	74	.10	.20	4.17	.48
PL-78	76	.10	.20	4.17	.48
PL-910	76	.10	.20	4.17	.48

[1] Vol_{CN} = SCS Curve Number, Hydrograph Volume
Vol_{GA} = Green-Ampt Infiltration, Hydrograph Volume

The Green-Ampt infiltration method tends to produce more defined peaks with less volume of water in the hydrograph. Figure 4 indicates that the calibration using the Green-Ampt method is not as satisfactory as the Curve Number method. The second storm calibration using curve numbers was excellent (Figure 6) and therefore, it was decided to apply the SCS curve number method in the HEC-1 simulation for the Broadmoor South watersheds. The curve number approach will be more conservative with respect to the hydrograph volume.

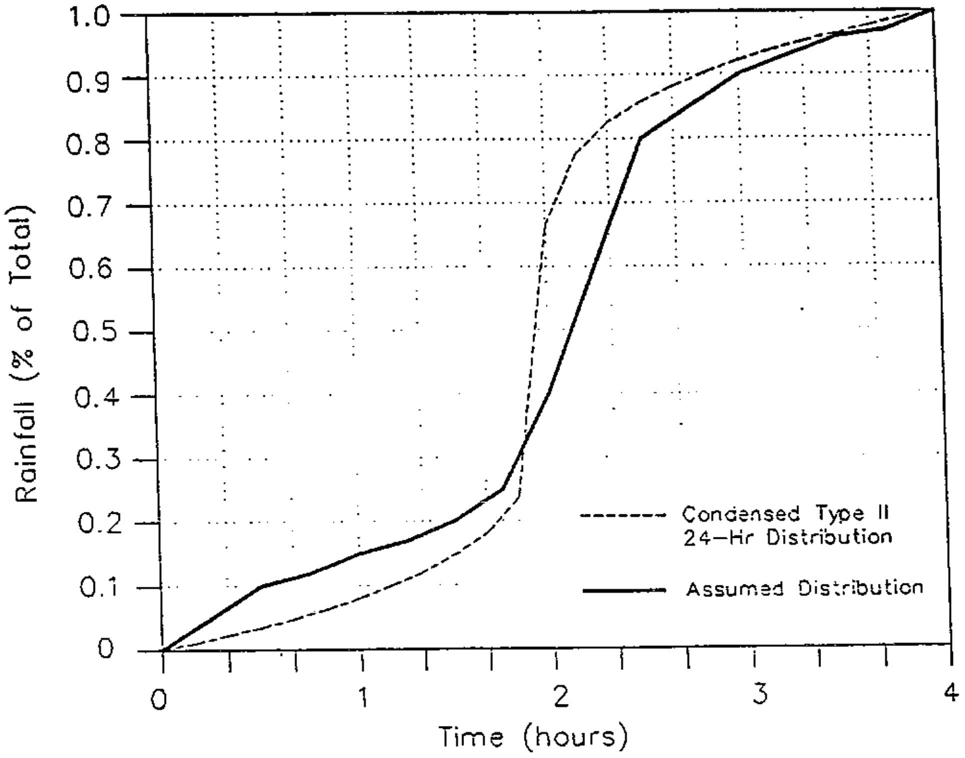


Figure 5. Storm Distribution for the Second Rock Creek Calibration

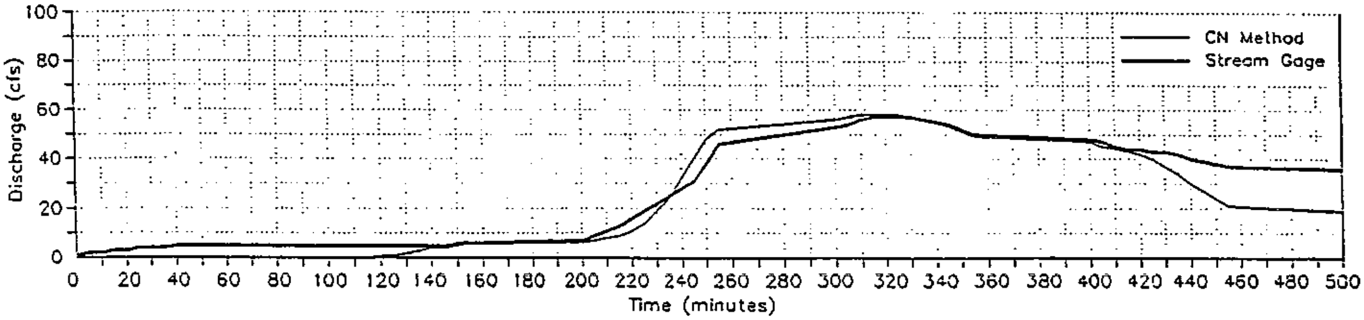


Figure 6. Rock Creek Storm Calibration for the July 19 and 20, 1985 Storm
Using the SCS Curve Number Method

Hydrologic Modeling of the Broadmoor South Watersheds

The Broadmoor South Property is located on a series of coalescing alluvial fans formed by a number of small watersheds on the east slope of Cheyenne Mountain. The basins are labeled as numbers 3 to 17 in Figure 7 and extend from the NORAD entrance north to the Cheyenne Mountain Zoo. Basin 12, Fishers Canyon is the largest of these study basins. Subbasins modeled in the HEC-1 simulation as individual watershed units are identified by hyphenated numbers, e.g. 12-1.

Watersheds along the east slope of Cheyenne Mountain are extremely steep with numerous exposed rock outcrops. Cheyenne Mountain reaches an elevation of approximately 9,440 ft and the watershed alluvial fans begin between an elevation of 7,000 and 7,200 ft. Channel slopes in the upper watershed approach 60%. Rock outcrops are near vertical in many areas. Vegetation is sparse to moderate, with the north facing slope having slightly more vegetative cover. The alluvial fan project area lies in the lower Montane ecozone, an upland forest area of conifers and deciduous trees dominated by ponderosa pines, lodgepole, and blue spruce. Scrub oak are found throughout the basin along the channels.

For the purpose of hydrologic modeling, some impervious area (area of zero infiltration) in each basin was designated. The percent impervious area was estimated from aerial photos and the USGS Cheyenne Mountain 7.5 minute quadrangle map showing relative amounts of soil and bedrock. Based on the exposed bedrock estimates for the Rock Creek basin, percent impervious areas were estimated for the Broadmoor South watersheds. The impervious area was assumed to be approximately 5% of the estimated area of exposed bedrock.

Comparisons were made between the physical, topographic, and vegetative features of the Broadmoor South and the Rock Creek subbasins to estimate SCS curve numbers. The curve numbers for all the subbasins are presented in Appendix Tables A.1 and A.2. The curve numbers range from 74 to 76. For comparison, RCI (1989) used curve numbers of 75 and 76 for the upper watershed of Fishers's Canyon. Weiss (1987), Drexel Barrell (1990) and KLH (1982) applied a range of curve numbers to the hydrologic analysis of various urbanized watersheds. The range of curve numbers for analyses similar to the Broadmoor South was from 69 to 80.

The Green-Ampt infiltration parameters were also applied to determine excess rainfall on the Broadmoor South watersheds. Initially, the assigned parameters were the same as those used in the calibration of Rock Creek on the basis of elevation and vegetative cover. The parameters were then adjusted to first match the peak discharge and second to match the volume for the 100-year, 2-hr storm predicted by the curve number method for each basin. The final Green-Ampt parameters are presented in Appendix Tables A.1 and A.2.

Figure 7. Cheyenne Mountain Watersheds and Subbasins

The peak discharges for the 10-yr and 100-yr, 2-hr and 24-hr storms using the SCS curve number method are shown in Table 5. The unit peak runoff for the 100-yr flood is presented in the last column of Table 5. RCI (1989) reported unit runoff for watersheds in the Colorado Springs area ranging from 950 to 1,140 cfs/mi^2 for basins less than 2 mi^2. The computed unit runoffs in this study generally fall within this range. The computed volumes and peaks using the Green-Ampt infiltration method are shown in Table 6.

Table 5 South Broadmoor Watershed HEC-1 Results

Basin # File	Area (mi^2)	HEC-1 Peak Flow (cfs) Using Curve Number Method				100-Year Peak Runoff (cfs/mi^2)
		10-Year		100-Year		
		2-hr	24-hr	2-hr	24-hr	2-hr
Basin 3	0.023	8	7	25	15	1,110
Basin 56	0.064	22	13	72	42	1,120
Basin 7	0.014	5	4	15	2	1,110
Basin 8	0.093	34	30	100	64	1,100
Basin 9	0.085	29	27	94	29	1,100
Basin 1011	0.072	24	21	77	47	1,070
Basin 12	0.494	190	140	560	310	1,140
Basin 13	0.045	15	14	50	30	1,100
Basin 14	0.132	49	42	150	87	1,130
Basin 15	0.126	48	31	150	87	1,170
Basin 16	0.131	72	55	190	110	1,440
Basin 17	0.055	19	16	50	30	1,030

The 100-yr, 2-hr storm results in a higher peak discharge than that computed for the 100-yr, 24 hour storm and was selected as the design storm. The 100-year, 2-hr hydrograph for Fisher's Canyon (Basin 12) is shown in Figure 8. This flood hydrograph is typical of the 100-yr flood hydrographs for other Broadmoor South watersheds. The HEC-1 simulated 100-yr, 2-hr hydrograph at the canyon mouth will constitute the inflow for the alluvial fan flood routing simulation to be performed with the 2-dimensional flood routing model FLO-2D.

Table 6. HEC-1 Results for South Broadmoor Watersheds
Comparing Curve Number and Green-Ampt Infiltration Methods for the 100-Year Storm

Basin	Curve Number		Green-Ampt	
	Peak (cfs)	Volume (a-ft)	Volume (a-ft) Matching Peak	Peak (cfs) Matching Vol.
3	25	1.20	0.34	82
56	72	1.39	0.40	230
7	15	0.71	0.22	48
8	100	5.05	1.81	310
9	94	4.57	1.56	300
1011	77	3.80	1.43	220
12	560	28.80	9.91	1,500
13	50	2.40	0.93	153
14	150	7.14	2.14	430
15	150	7.10	2.09	440
16	190	9.38	2.57	570
17	57	2.66	0.63	190

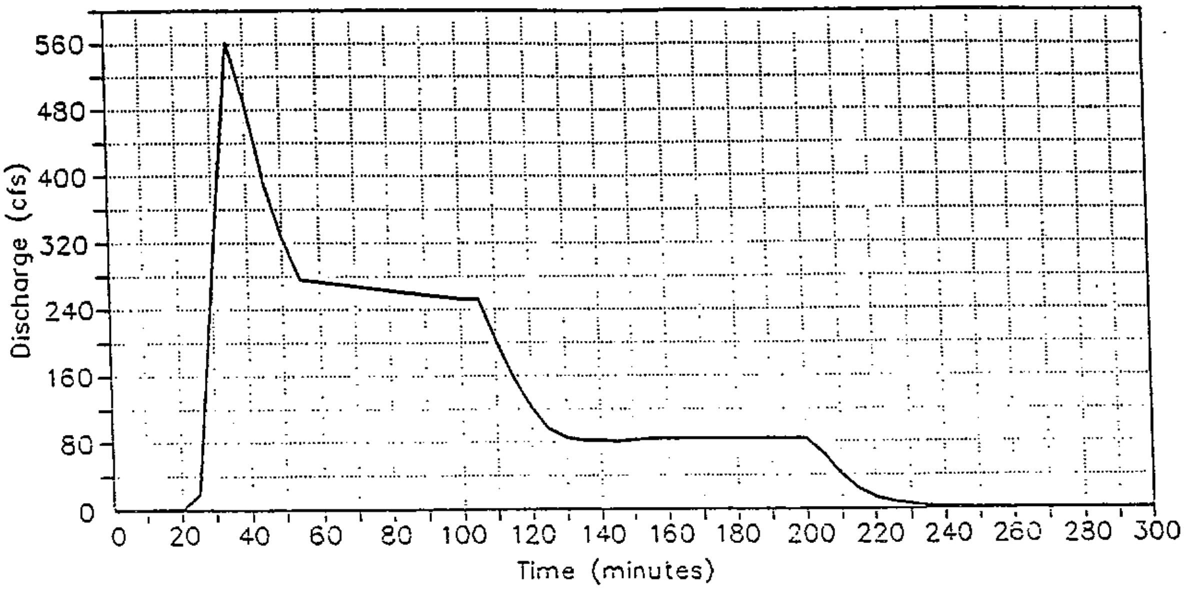


Figure 8. 100-Yr, 2-Hr Storm Discharge Hydrograph Fisher's Canyon, Basin 12

Summary

The Broadmoor South property extending from the NORAD entrance north to the Cheyenne Mountain Zoo is subject to flooding from the watersheds on the east slope of the Cheyenne Mountain. These watersheds, ranging in size from 0.014 to 0.494 square miles, have historically debouched mud and debris flows over the property and created small coalescing alluvial fans. To delineate the water flood and mud/debris flow hazard on the Broadmoor South property, a design rain storm was simulated in the upper watersheds.

The Broadmoor South watersheds were ungaged. It was necessary, therefore, to predict the flood hydrograph at the watershed mouth by simulating the rainfall-runoff for a design storm using the Corps of Engineers HEC-1 hydrologic model. The City of Colorado Springs and El Paso County Drainage Criteria Manual was consulted in formulating the design storm. Based on the Drainage Manual criteria, the selected design storm was the 100-yr 2-hr storm with a total rainfall of 3.1 inches. The Manual prescribed 2-hr rainfall distribution was applied in the HEC-1 simulation.

Hydrologic HEC-1 parameters for the Broadmoor South watersheds were calibrated using a small gaged basin (Rock Creek) to the south of Cheyenne Mountain. Two storms were calibrated for peak flow and volume. Both the SCS curve number and the Green-Ampt infiltration methods for computing runoff were attempted. The calibrated SCS curve numbers correlated well with the curve numbers used in other local studies. The second HEC-1 calibration resulted an excellent correlation with the measured runoff.

Flood hydrographs at the fan apex for the 100-yr flood were computed with HEC-1 for all the Broadmoor South watersheds. Peak discharges ranged from 15 to 560 cfs with unit runoff ranging from 1,030 to 1,440 cfs/mi^2. The unit runoff values fell with the range of unit runoffs computed in other studies. These flood hydrographs will be bulked for mud and debris flow simulation over the alluvial fans using a two-dimensional flood routing model FLO-2D.

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Appendix A

Hydrologic Parameters for the Broadmoor South Watersheds

Table A.1 Broadmoor South Watersheds Hydrologic Parameters For Matching the Peak Discharge Computed with Curve Numbers

Basin	Curve Numbers CN	Initial Loss (in)	Volume Moisture Deficiency (in)	Wetting Front Suction (in)	Hydraulic Conductivity (in)
3	74	0.40	0.30	5.50	1.55
5	74	0.40	0.30	5.50	1.43
6	74	0.40	0.30	5.50	1.43
7	74	0.40	0.30	5.05	1.40
8-1	74	0.40	0.30	5.00	1.50
8-2	75	0.40	0.30	5.10	1.50
8-3	74	0.40	0.30	5.10	1.50
8-4	74	0.40	0.30	5.10	1.50
9	74	0.40	0.30	5.13	1.50
1011-1	74	0.40	0.30	5.27	1.30
1011-2	74	0.40	0.30	5.27	1.30
1011-3	74	0.40	0.30	5.40	1.40
12-1	76	0.40	0.30	5.20	1.48
12-2	76	0.40	0.30	5.20	1.48
12-3	76	0.40	0.30	5.20	1.48
12-4	75	0.40	0.30	5.20	1.48
12-5	76	0.40	0.30	5.20	1.48
12-6	76	0.40	0.30	5.20	1.48
12-7	75	0.40	0.30	5.30	1.60
12-8	75	0.40	0.30	5.30	1.60
12-9	75	0.40	0.30	5.30	1.60
12-10	75	0.40	0.30	5.30	1.60
12-11	74	0.40	0.30	5.40	1.70
13	74	0.40	0.30	5.00	1.37
14-1	74	0.40	0.30	5.20	1.70
14-2	75	0.40	0.30	5.20	1.68

Table A.1: Broadmoor South Watersheds Hydrologic Parameters For Matching the Peak Discharge Computed with Curve Numbers

Basin	Curve Numbers CN	Initial Loss (in)	Volume Moisture Deficiency (in)	Wetting Front Suction (in)	Hydraulic Conductivity (in)
14-3	76	0.40	0.30	5.20	1.58
14-4	76	0.40	0.30	5.20	1.55
14-5	76	0.40	0.30	5.20	1.55
15-1	74	0.40	0.30	5.60	1.80
15-2	76	0.40	0.30	5.55	1.70
15-3	75	0.40	0.30	5.35	1.38
16-1	74	0.40	0.30	5.50	1.70
16-2	74	0.40	0.30	5.50	1.70
16-3	76	0.40	0.30	5.40	1.60
16-4	75	0.40	0.30	5.42	1.65
17	74	0.40	0.30	5.50	1.67

Table A.2 Broadmoor South Watersheds Hydrologic Parameters For Matching the Volume Computed with Curve Numbers

Basin	Curve Number CN	Initial Loss (in)	Volume Moisture Deficiency (in)	Wetting Front Suction (in)	Hydraulic Conductivity (in)
3	74	0.30	0.20	4.40	0.77
5	74	0.30	0.20	4.50	0.78
6	74	0.30	0.20	4.50	0.78
7	74	0.30	0.20	4.40	0.77
8-1	74	0.30	0.20	4.30	0.77
8-2	75	0.30	0.20	4.30	0.80
8-3	74	0.30	0.20	4.30	0.80
8-4	74	0.30	0.20	4.30	0.80
9	74	0.30	0.20	4.40	0.76
1011-1	74	0.30	0.20	4.40	0.76
1011-2	74	0.30	0.20	4.40	0.76
1011-3	74	0.30	0.20	4.40	0.80
12-1	76	0.30	0.20	4.40	0.63
12-2	76	0.30	0.20	4.40	0.63
12-3	76	0.30	0.20	4.40	0.63
12-4	75	0.30	0.20	4.40	0.63
12-5	76	0.30	0.20	4.40	0.63
12-6	76	0.30	0.20	4.40	0.63
12-7	75	0.30	0.20	4.50	0.80
12-8	75	0.30	0.20	4.50	0.80
12-9	75	0.30	0.20	4.40	0.80
12-10	75	0.30	0.20	4.50	0.80
12-11	74	0.30	0.20	4.50	0.80
13	74	0.30	0.20	4.40	0.74
14-1	74	0.30	0.20	4.50	0.75
14-2	75	0.30	0.20	4.50	0.75

Table A.2. Broadmoor South Watersheds Hydrologic Parameters For Matching the Volume Computed with Curve Numbers

Basin	Curve Number CN	Initial Loss (in)	Volume Moisture Deficiency (in)	Wetting Front Suction (in)	Hydraulic Conductivity (in)
14-3	76	0.30	0.20	4.40	0.65
	76	0.30	0.20	4.40	0.65
14-5	76	0.30	0.20	4.40	0.65
15-1	74	0.30	0.20	4.60	0.80
15-2	76	0.30	0.20	4.40	0.64
15-3	75	0.30	0.20	4.50	0.70
16-1	74	0.30	0.20	4.50	0.80
16-2	74	0.30	0.20	4.50	0.80
16-3	76	0.30	0.20	4.40	0.70
16-4	75	0.30	0.20	4.50	0.71
17	74	0.30	0.20	4.45	0.76

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                THIS PROGRAM REPLACES ALL PREVIOUS VERSIONS OF HEC-1 KNOWN AS HEC1 (JAN 73), HEC1GS, HEC1DB, AND HEC1KW.

                THE DEFINITIONS OF VARIABLES -RTIMP- AND -RTIOR- HAVE CHANGED FROM THOSE USED WITH THE 1973-STYLE INPUT STRUCTURE
                THE DEFINITION OF -AMSKK- ON RM-CARD WAS CHANGED WITH REVISIONS DATED 28 SEP 81. THIS IS THE FORTRAN77 VERSION
                NEW OPTIONS: DAMBREAK OUTFLOW SUBMERGENCE , SINGLE EVENT DAMAGE CALCULATION, DSS:WRITE STAGE FREQUENCY,
                DSS:READ TIME SERIES AT DESIRED CALCULATION INTERVAL   LOSS RATE:GREEN AND AMPT INFILTRATION
                KINEMATIC WAVE: NEW FINITE DIFFERENCE ALGORITHM


1                                                    HEC-1 INPUT                                                   PAGE  1

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                  3            ID        MODIFICATION OF FLO ENGINEERING,INC STUDY/FULL BASIN
                               *DIAGRAM
                  4            IT       1 22SEP97    1200    1500
                  5            IN       5
                  6            IO       5       0

                  7            KK   B12-1
                  8            KM        RUNOFF FROM SDA 12-1
                  9            BA    .089
                 10            PB     1.6
                 11            PI     .01     .03     .04     .07     .12     .22     .12     .07     .05     .04
                 12            PI     .03     .03     .03     .02     .02     .01     .01     .01     .01     .01
                 13            PI     .01     .01     .01     .01
                 14            LS       0      76       6
                 15            UD    .126

                 16            KK   B12-2
                 17            KM        RUNOFF FROM SDA 12-2
                 18            BA    .028
                 19            LS       0      76       6
                 20            UD    .113

                 21            KK     DP1
                 22            KM        COMBINE FLOWS FROM SDAs 12-1, 12-2
                 23            HC       2

                 24            KK     A-A
                 25            KM        ROUTE FLOWS FROM CP1 TO CP2
                 26            RS       1    STOR       0
                 27            RC    0.12     .08    0.12     630    0.24
                 28            RX       0       5      10      20      28      38      43      48
                 29            RY      15    12.5      10       0       0      10    12.5      15

                 30            KK   B12-3
                 31            KM        RUNOFF FROM SDA 12-3
                 32            BA    .027
                 33            LS       0      76       6
                 34            UD    .145

                 35            KK   B12-4
                 36            KM        RUNOFF FROM SDA 12-4
```

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           37           BA    .038
           38           LS      0       75        6
           39           UD    .110

           40           KK   B12-7
           41           KM        RUNOFF FROM SDA 12-7
           42           BA    .016
           43           LS      0       75        5
           44           UD    .134
1                                                HEC-1 INPUT                                         PAGE  2

          LINE          ID.......1.......2.......3.......4.......5.......6.......7.......8.......9......10


           45           KK     DP2
           46           KM        COMBINE CP1 & SDAs 12-3, 12-4, 12-7
           47           HC       4

           48           KK     B-B
           49           KM        ROUTE FLOWS FROM CP2 TO CP3
           50           RS       1     STOR       0
           51           RC    0.12     .08    0.12      790     0.19
           52           RX       0       5      10       20       28       38       43       48
           53           RY      15    12.5      10        0        0       10     12.5       15

           54           KK   B12-5
           55           KM        RUNOFF FROM SDA 12-5
           56           BA    .081
           57           LS      0       76       10
           58           UD    .154

           59           KK   B12-8
           60           KM        RUNOFF FROM SDA 12-8
           61           BA    .023
           62           LS      0       75        5
           63           UD    .077

           64           KK     DP3
           65           KM        COMBINE FLOWS FROM CP2 & SDAs 12-5, 12-8
           66           HC       3

           67           KK     C-C
           68           KM        ROUTE FLOW FROM CP3 TO CP4
           69           RS       1     STOR       0
           70           RC    0.12     .08    0.12      650     0.26
           71           RX       0       5      10       20       28       38       43       48
           72           RY      15    12.5      10        0        0       10     12.5       15

           73           KK   B12-6
           74           KM        RUNOFF FROM SDA 12-6
           75           BA    .061
           76           LS      0       76       10
           77           UD    .129

           78           KK   B12-9
           79           KM        RUNOFF FROM SDA 12-9
           80           BA    .021
           81           LS      0       75        4
           82           UD    .112

           83           KK     DP4
           84           KM        COMBINE FLOWS FROM CP3 & SDAs 12-6, 12-9
           85           HC       3
1                                                HEC-1 INPUT                                         PAGE  3

          LINE          ID.......1.......2.......3.......4.......5.......6.......7.......8.......9......10


           86           KK     D-D
           87           KM        ROUTE FLOWS FROM CP4 TO CP5
           88           RS       1     STOR       0
           89           RC    0.12     .08    0.12     1420     0.19
           90           RX       0       5      10       20       28       38       43       48
           91           RY      15    12.5      10        0        0       10     12.5       15

           92           KK   B1210
           93           KM        RUNOFF FROM SDA 12-10
           94           BA    .069
           95           LS      0       75        5
           96           UD    .170
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       97           KK      DP5
       98           KM         COMBINE FLOWS FROM CP4 & SDA 1210
       99           HC         2

      100           KK      E-E
      101           KM         ROUTE FLOW FROM CP5 TO CP6
      102           RS         1    STOR        0
      103           RC      0.12      .08     0.12     1420     0.11
      104           RX         0        5       10       20       28       38       43       48
      105           RY        15     12.5       10        0        0       10     12.5       15

      106           KK    B1211
      107           KM         RUNOFF FROM SDA 12-11
      108           BA      .041
      109           LS         0       74       10
      110           UD      .073

      111           KK      DP6
      112           KM         COMBINE DP5 & 1211
      113           HC         2

      114           KK      F-F
      115           KM         ROUTE FLOW FROM 12-11 TO 1011-1
      116           RS         1    STOR        0
      117           RC      0.12      .08     0.12     1200      .13
      118           RX         0        5       10       20       28       38       43       48
      119           RY        15     12.5       10        0        0       10     12.5       15

      120           KK   B10111
      121           KM         RUNOFF FROM SDA 1011-1
      122           BA      .035
      123           LS         0       74        7
      124           UD      .160

      125           KK   B10112
      126           KM         RUNOFF FROM SDA 1011-2
      127           BA      .037
      128           LS         0       74        7
      129           UD      .160
1                                              HEC-1 INPUT                                          PAGE  4

     LINE           ID.......1.......2.......3.......4.......5.......6.......7.......8.......9......10


      130           KK      DP8
      131           KM         COMBINE FLOW FROM SDA 1012 & CP6A
      132           HC         3

      133           KK      G-G
      134           KM         ROUTE FLOW FROM DP8 TO DP300
      135           RS         1    STOR        0
      136           RC      0.12      .08     0.12     1200      .12
      137           RX         0        5       10       20       28       38       43       48
      138           RY        15     12.5       10        0        0       10     12.5       15

      139           KK     300A
      140           KM         RUNOFF FROM 300A
      141           BA      .049
      142           LS         0       58        4
      143           UD      .313

      144           KK    DP300
      145           KM         COMBINE FLOWS FROM CP8 & SDA 300A
      146           HC         2

      147           KK       B9
      148           KM         RUNOFF FROM SDA 9
      149           BA      .085
      150           LS         0       74        4
      151           UD      .125

      152           KK      H-H
      153           KM         ROUTE FLOW FROM B9 THRU SDA 300B
      154           RS         1    STOR        0
      155           RC      0.12      .08     0.12     1200      .25
      156           RX         0        5       10       20       28       38       43       48
      157           RY        15     12.5       10        0        0       10     12.5       15

      158           KK     300B
      159           KM         RUNOFF FROM 300B
      160           BA      .026
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         161           LS       0       58        4
         162           UD    .247

         163           KK      DP9
         164           KM         COMBINE SDA B9 & 300B
         165           HC       2

         166           KK    DP301
         167           KM         COMBINE FLOWS FROM CP300 & SDA 300B
         168           HC       2

         169           KK      I-I
         170           KM         ROUTE FLOW FROM B9 THRU SDA 300B
         171           RS       1     STOR        0
         172           RC    0.12     .08     0.12     1800      .17
         173           RX       0       4      5.5      6.5     14.5     15.5       17       21
         174           RY       7       5        2        0        0        2        5        7
1                                                         HEC-1 INPUT                                        PAGE  5

        LINE           ID.......1.......2.......3.......4.......5.......6.......7.......8.......9......10


         175           KK     300C
         176           KM         RUNOFF FROM SDA 300C
         177           BA     .06
         178           LS       0       58        4
         179           UD    .288

         180           KK    DP302
         181           KM         COMBINE FLOWS FROM CP301 & 300C
         182           HC       2

         183           KK     100A
         184           KM         RUNOFF FROM SDA 100A
         185           BA    .048
         186           LS       0       58        4
         187           UD    .271

         188           KK     100B
         189           KM         RUNOFF FROM SDA 100B
         190           BA    .022
         191           LS       0       58        4
         192           UD    .260

         193           KK    DP101
         194           KM         COMBINE FLOWS FROM CP100 & SDA 100B
         195           HC       2

         196           KK     100C
         197           KM         RUNOFF FROM SDA 100C
         198           BA    .035
         199           LS       0       58        4
         200           UD    .292

         201           KK    DP102
         202           KM         COMBINE FLOWS FROM CP101 & SDA 100C
         203           HC       2

         204           KK     200A
         205           KM         RUNOFF FROM 200A
         206           BA    .035
         207           LS       0       58        4
         208           UD    .281

         209           KK     200C
         210           KM         RUNOFF FROM 200C
         211           BA    .051
         212           LS       0       58        4
         213           UD    .281

         214           KK    DP200
         215           KM         COMBINE FLOWS FROM SDAs 200A & 200C
         216           HC       2
1                                                         HEC-1 INPUT                                        PAGE  6

        LINE           ID.......1.......2.......3.......4.......5.......6.......7.......8.......9......10


         217           KK     200B
         218           KM         RUNOFF FROM 200B
         219           BA    .017
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          220          LS       0      58       4
          221          UD    .281

          222          KK     B34
          223          KM        RUNOFF FROM SDA        34
          224          BA    .023
          225          LS       0      74       7
          226          UD    .125

          227          KK     J-J
          228          KM        ROUTE FLOW FROM B3 THRU 500C
          229          RS       1    STOR       0
          230          RC    0.12     .08    0.12    1500     .21
          231          RX       0       5      10      20      28      38      43      48
          232          RY      15    12.5      10       0       0      10    12.5      15

          233          KK    500C
          234          KM         RUNOFF FROM 500C
          235          BA    .015
          236          LS       0      58       4
          237          UD    .208

          238          KK   DP345
          239          KM        COMBINE SDAs 34 & 500C
          240          HC       2

          241          KK      B5
          242          KM        RUNOFF FROM SDA 5
          243          BA    .042
          244          LS       0      74       7
          245          UD    .131

          246          KK      B6
          247          KM        RUNOFF FROM SDA 6
          248          BA    .022
          249          LS       0      74       7
          250          UD    .131

          251          KK    DP56
          252          KM        COMBINE FLOWS FROM SDAs 5&6
          253          HC       2

          254          KK     K-K
          255          KM        ROUTE FLOW FROM DP 56 THRU 500A
          256          RS       1    STOR       0
          257          RC    0.12     .08    0.12    2100     .22
          258          RX       0       5      10      20      28      38      43      48
          259          RY      15    12.5      10       0       0      10    12.5      15
1                                                       HEC-1 INPUT                                             PAGE  7

         LINE          ID.......1.......2.......3.......4.......5.......6.......7.......8.......9......10


          260          KK    500A
          261          KM        RUNOFF FROM SDA 500A
          262          BA    .036
          263          LS       0      58       4
          264          UD    .313

          265          KK   DP500
          266          KM        COMBINE FLOWS FROM CP56&500A
          267          HC       3

          268          KK    500B
          269          KM        RUNOFF FROM SDA 500B
          270          BA    .009
          271          LS       0      58       4
          272          UD    .208

          273          KK   DP501
          274          KM        COMBINE FLOWS FROM CP5A&500B
          275          HC       2

          276          KK      B7
          277          KM        RUNOFF FROM SDA 7
          278          BA    .014
          279          LS       0      74       7
          280          UD    .107

          281          KK    B8-1
          282          KM        RUNOFF FROM SDA 8-1
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        283              BA    .056
        284              LS      0       74        7
        285              UD    .113

        286              KK    B8-2
        287              KM         RUNOFF FROM SDA 8-2
        288              BA    .016
        289              LS      0       74        7
        290              UD    .086

        291              KK     DP7
        292              KM         COMBINE FLOWS FROM SDAs 8-1, 8-2
        293              HC        2

        294              KK    B8-3
        295              KM         RUNOFF FROM SDA 8-3
        296              BA    .021
        297              LS      0       74        7
        298              UD    .202

        299              KK    DP7A
        300              KM         COMBINE FLOW FROM CP7 & SDA 8-3 &B7
        301              HC        3
1                                               HEC-1 INPUT                                               PAGE  8

       LINE              ID.......1.......2.......3.......4.......5.......6.......7.......8.......9......10


        302              KK    400A
        303              KM         RUNOFF FROM SDA     400A
        304              BA     .02
        305              LS      0       58        4
        306              UD    .506

        307              KK   DP401
        308              KM         COMBINE FLOWS FROM DP7A & SDA 400A
        309              HC        2

        310              KK    400B
        311              KM         RUNOFF FROM SDA     400B
        312              BA     .01
        313              LS      0       58        4
        314              UD    .406

        315              KK   DP402
        316              KM         COMBINE FLOWS FROM DP402& SDA 400B
        317              HC        2
        318              ZZ
1
              SCHEMATIC DIAGRAM OF STREAM NETWORK
 INPUT
  LINE     (V) ROUTING          (--->) DIVERSION OR PUMP FLOW

   NO.     (.) CONNECTOR        (<---) RETURN OF DIVERTED OR PUMPED FLOW

     7      B12-1
               .
               .
    16         .       B12-2
               .           .
               .           .
    21       DP1............
               V
               V
    24       A-A
               .
               .
    30         .       B12-3
               .           .
               .           .
    35         .           .       B12-4
               .           .           .
               .           .           .
    40         .           .           .       B12-7
               .           .           .           .
               .           .           .           .
    45       DP2............................................
               V
               V
    48       B-B
               .
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             .
 54          .       B12-5
             .           .
             .           .
 59          .           .       B12-8
             .           .           .
             .           .           .
 64        DP3........................
             V
             V
 67        C-C
             .
             .
 73          .       B12-6
             .           .
             .           .
 78          .           .       B12-9
             .           .           .
             .           .           .
 83        DP4........................
             V
             V
 86        D-D
             .
             .
 92          .       B1210
             .           .
             .           .
 97        DP5............
             V
             V
100        E-E
             .
             .
106          .       B1211
             .           .
             .           .
111        DP6............
             V
             V
114        F-F
             .
             .
120          .      B10111
             .           .
             .           .
125          .           .      B10112
             .           .           .
             .           .           .
130        DP8........................
             V
             V
133        G-G
             .
             .
139          .        300A
             .           .
             .           .
144      DP300............
             .
             .
147          .          B9
             .           V
             .           V
152          .         H-H
             .           .
             .           .
158          .           .        300B
             .           .           .
             .           .           .
163          .         DP9............
             .           .
             .           .
166      DP301............
             V
             V
169        I-I
             .
             .
175          .        300C
             .           .
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              .           .
180       DP302............
              .
              .
183           .        100A
              .           .
              .           .
188           .           .        100B
              .           .           .
              .           .           .
193           .       DP101............
              .           .
              .           .
196           .           .        100C
              .           .           .
              .           .           .
201           .       DP102............
              .           .
              .           .
204           .           .        200A
              .           .           .
              .           .           .
209           .           .           .        200C
              .           .           .           .
              .           .           .           .
214           .           .       DP200............
              .           .           .
              .           .           .
217           .           .           .        200B
              .           .           .           .
              .           .           .           .
222           .           .           .           .         B34
              .           .           .           .           V
              .           .           .           .           V
227           .           .           .           .         J-J
              .           .           .           .           .
              .           .           .           .           .
233           .           .           .           .           .        500C
              .           .           .           .           .           .
              .           .           .           .           .           .
238           .           .           .           .       DP345............
              .           .           .           .           .
              .           .           .           .           .
241           .           .           .           .           .          B5
              .           .           .           .           .           .
              .           .           .           .           .           .
246           .           .           .           .           .           .          B6
              .           .           .           .           .           .           .
              .           .           .           .           .           .           .
251           .           .           .           .           .        DP56............
              .           .           .           .           .           V
              .           .           .           .           .           V
254           .           .           .           .           .         K-K
              .           .           .           .           .           .
              .           .           .           .           .           .
260           .           .           .           .           .           .        500A
              .           .           .           .           .           .           .
              .           .           .           .           .           .           .
265           .           .           .           .       DP500........................
              .           .           .           .           .
              .           .           .           .           .
268           .           .           .           .           .        500B
              .           .           .           .           .           .
              .           .           .           .           .           .
273           .           .           .           .       DP501............
              .           .           .           .           .
              .           .           .           .           .
276           .           .           .           .           .          B7
              .           .           .           .           .           .
              .           .           .           .           .           .
281           .           .           .           .           .           .        B8-1
              .           .           .           .           .           .           .
              .           .           .           .           .           .           .
286           .           .           .           .           .           .           .        B8-2
              .           .           .           .           .           .           .           .
              .           .           .           .           .           .           .           .
291           .           .           .           .           .           .         DP7............
              .           .           .           .           .           .           .
              .           .           .           .           .           .           .
294           .           .           .           .           .           .           .        B8-3
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                 .           .           .           .           .           .           .           .
   299           .           .           .           .           .       DP7A.........................
                 .           .           .           .           .           .
                 .           .           .           .           .           .
   302           .           .           .           .           .           .        400A
                 .           .           .           .           .                       .
                 .           .           .           .           .           .           .
   307           .           .           .           .           .      DP401.............
                 .           .           .           .           .           .
                 .           .           .           .           .           .
   310           .           .           .           .           .           .        400B
                 .           .           .           .           .                       .
                 .           .           .           .           .           .           .
   315           .           .           .           .           .      DP402.............

 (***) RUNOFF ALSO COMPUTED AT THIS LOCATION
1*****************************************                                                      ********************************
 *                                       *                                                      *
 *   FLOOD HYDROGRAPH PACKAGE  (HEC-1)   *                                                      *   U.S. ARMY CORPS OF ENGINEER
 *             JUN 09 1992               *                                                      *   HYDROLOGIC ENGINEERING CENT
 *            VERSION 4.0.3E             *                                                      *        609 SECOND STREET
 *                                       *                                                      *     DAVIS, CALIFORNIA 95616
 *  RUN DATE  12/05/97  TIME  16:42:30   *                                                      *         (916) 551-1748
 *                                       *                                                      *
 *****************************************                                                      ********************************




                                 BROADMOOR RESORT COMMUNITY (SOUTH) MASTER DRAINAGE PLAN
                                 5-YR, 2-HR      EXISTING
                                 MODIFICATION OF FLO ENGINEERING,INC STUDY/FULL BASIN

    6 IO          OUTPUT CONTROL VARIABLES
                        IPRNT          5  PRINT CONTROL
                        IPLOT          0  PLOT CONTROL
                        QSCAL         0.  HYDROGRAPH PLOT SCALE

      IT          HYDROGRAPH TIME DATA
                         NMIN          1  MINUTES IN COMPUTATION INTERVAL
                        IDATE    22SEP97  STARTING DATE
                        ITIME       1200  STARTING TIME
                           NQ       1500  NUMBER OF HYDROGRAPH ORDINATES
                       NDDATE    23SEP97  ENDING DATE
                       NDTIME       1259  ENDING TIME
                        ICENT         19  CENTURY MARK

                    COMPUTATION INTERVAL    0.02 HOURS
                         TOTAL TIME BASE   24.98 HOURS

           ENGLISH UNITS
                DRAINAGE AREA          SQUARE MILES
                PRECIPITATION DEPTH    INCHES
                LENGTH, ELEVATION      FEET
                FLOW                   CUBIC FEET PER SECOND
                STORAGE VOLUME         ACRE-FEET
                SURFACE AREA           ACRES
                TEMPERATURE            DEGREES FAHRENHEIT
1
                                                                RUNOFF SUMMARY
                                                        FLOW IN CUBIC FEET PER SECOND
                                                     TIME IN HOURS,  AREA IN SQUARE MILES

                                            PEAK    TIME OF        AVERAGE FLOW FOR MAXIMUM PERIOD          BASIN      MAXIMUM      TIME OF
          OPERATION        STATION          FLOW      PEAK                                                   AREA       STAGE      MAX STAGE
+                                                                   6-HOUR       24-HOUR       72-HOUR

          HYDROGRAPH AT
+                            B12-1            22.     0.70              3.            1.            1.       0.09

          HYDROGRAPH AT
+                            B12-2             7.     0.68              1.            0.            0.       0.03

          2 COMBINED AT
+                              DP1            29.     0.70              4.            1.            1.       0.12

          ROUTED TO
+                              A-A            28.     0.73              4.            1.            1.       0.12
+                                                                                                                         0.46        0.73
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```
              HYDROGRAPH AT
+                          B12-3       6.    0.73          1.         0.         0.      0.03

              HYDROGRAPH AT
+                          B12-4       9.    0.68          1.         0.         0.      0.04

              HYDROGRAPH AT
+                          B12-7       3.    0.73          0.         0.         0.      0.02

              4 COMBINED AT
+                            DP2      46.    0.72          6.         2.         2.      0.20

              ROUTED TO
+                            B-B      46.    0.75          6.         2.         2.      0.20
+                                                                                                 0.81       0.75

              HYDROGRAPH AT
+                          B12-5      23.    0.72          3.         1.         1.      0.08

              HYDROGRAPH AT
+                          B12-8       5.    0.65          1.         0.         0.      0.02

              3 COMBINED AT
+                            DP3      73.    0.73         10.         3.         2.      0.30

              ROUTED TO
+                            C-C      73.    0.75         10.         3.         2.      0.30
+                                                                                                 0.94       0.75

              HYDROGRAPH AT
+                          B12-6      18.    0.68          2.         1.         1.      0.06

              HYDROGRAPH AT
+                          B12-9       4.    0.72          1.         0.         0.      0.02

              3 COMBINED AT
+                            DP4      94.    0.75         13.         3.         3.      0.38

              ROUTED TO
+                            D-D      92.    0.78         13.         3.         3.      0.38
+                                                                                                 1.19       0.78

              HYDROGRAPH AT
+                          B1210      13.    0.78          2.         1.         0.      0.07

              2 COMBINED AT
+                            DP5     105.    0.78         15.         4.         4.      0.45

              ROUTED TO
+                            E-E     102.    0.83         15.         4.         4.      0.45
+                                                                                                 1.53       0.83

              HYDROGRAPH AT
+                          B1211      11.    0.62          1.         0.         0.      0.04

              2 COMBINED AT
+                            DP6     109.    0.82         17.         4.         4.      0.49

              ROUTED TO
+                            F-F     108.    0.87         17.         4.         4.      0.49
+                                                                                                 1.50       0.87

              HYDROGRAPH AT
+                         B10111       7.    0.75          1.         0.         0.      0.04

              HYDROGRAPH AT
+                         B10112       7.    0.75          1.         0.         0.      0.04

              3 COMBINED AT
+                            DP8     121.    0.85         19.         5.         5.      0.57

              ROUTED TO
+                            G-G     120.    0.88         19.         5.         5.      0.57
+                                                                                                 1.64       0.88

              HYDROGRAPH AT
+                           300A       3.    0.80          0.         0.         0.      0.05

              2 COMBINED AT
+                          DP300     122.    0.88         19.         5.         5.      0.62
```

```
           HYDROGRAPH AT
+                          B9      15.    0.73        2.        1.        1.     0.09

           ROUTED TO
+                         H-H      14.    0.78        2.        1.        1.     0.09
+                                                                                         0.22      0.78

           HYDROGRAPH AT
+                        300B       2.    0.72        0.        0.        0.     0.03

           2 COMBINED AT
+                         DP9      16.    0.78        2.        1.        1.     0.11

           2 COMBINED AT
+                       DP301     136.    0.88       22.        5.        5.     0.73

           ROUTED TO
+                         I-I     134.    0.92       22.        5.        5.     0.73
+                                                                                         1.68      0.92

           HYDROGRAPH AT
+                        300C       3.    0.77        0.        0.        0.     0.06

           2 COMBINED AT
+                       DP302     137.    0.92       22.        6.        5.     0.79

           HYDROGRAPH AT
+                        100A       3.    0.75        0.        0.        0.     0.05

           HYDROGRAPH AT
+                        100B       1.    0.73        0.        0.        0.     0.02

           2 COMBINED AT
+                       DP101       4.    0.75        1.        0.        0.     0.07

           HYDROGRAPH AT
+                        100C       2.    0.77        0.        0.        0.     0.04

           2 COMBINED AT
+                       DP102       6.    0.75        1.        0.        0.     0.11

           HYDROGRAPH AT
+                        200A       2.    0.77        0.        0.        0.     0.04

           HYDROGRAPH AT
+                        200C       3.    0.77        0.        0.        0.     0.05

           2 COMBINED AT
+                       DP200       5.    0.77        1.        0.        0.     0.09

           HYDROGRAPH AT
+                        200B       1.    0.77        0.        0.        0.     0.02

           HYDROGRAPH AT
+                         B34       5.    0.70        1.        0.        0.     0.02

           ROUTED TO
+                         J-J       5.    0.77        1.        0.        0.     0.02
+                                                                                         0.08      0.77

           HYDROGRAPH AT
+                        500C       1.    0.68        0.        0.        0.     0.01

           2 COMBINED AT
+                       DP345       5.    0.75        1.        0.        0.     0.04

           HYDROGRAPH AT
+                          B5       9.    0.72        1.        0.        0.     0.04

           HYDROGRAPH AT
+                          B6       5.    0.72        1.        0.        0.     0.02

           2 COMBINED AT
+                        DP56      13.    0.72        2.        0.        0.     0.06

           ROUTED TO
+                         K-K      12.    0.80        2.        0.        0.     0.06
+                                                                                         0.20      0.80

           HYDROGRAPH AT
+                        500A       2.    0.80        0.        0.        0.     0.04
```

```
         3 COMBINED AT
+                         DP500        19.    0.78          3.         1.         1.       0.14

         HYDROGRAPH AT
+                          500B         1.    0.68          0.         0.         0.       0.01

         2 COMBINED AT
+                         DP501        20.    0.78          3.         1.         1.       0.15

         HYDROGRAPH AT
+                            B7         3.    0.68          0.         0.         0.       0.01

         HYDROGRAPH AT
+                          B8-1        12.    0.68          2.         0.         0.       0.06

         HYDROGRAPH AT
+                          B8-2         4.    0.65          0.         0.         0.       0.02

         2 COMBINED AT
+                           DP7        15.    0.68          2.         1.         1.       0.07

         HYDROGRAPH AT
+                          B8-3         4.    0.80          1.         0.         0.       0.02

         3 COMBINED AT
+                          DP7A        22.    0.70          3.         1.         1.       0.11

         HYDROGRAPH AT
+                          400A         1.    1.00          0.         0.         0.       0.02

         2 COMBINED AT
+                         DP401        22.    0.70          3.         1.         1.       0.13

         HYDROGRAPH AT
+                          400B         0.    0.88          0.         0.         0.       0.01

         2 COMBINED AT
+                         DP402        22.    0.70          3.         1.         1.       0.14


 *** NORMAL END OF HEC-1 ***
```

```
1*****************************************                                                   ********************************
 *                                       *                                                   *
 *   FLOOD HYDROGRAPH PACKAGE  (HEC-1)   *                                                   *    U.S. ARMY CORPS OF ENGINEER
 *              JUN 09 1992              *                                                   *    HYDROLOGIC ENGINEERING CENT
 *            VERSION 4.0.3E             *                                                   *          609 SECOND STREET
 *                                       *                                                   *       DAVIS, CALIFORNIA 95616
 *  RUN DATE  12/02/97  TIME  11:40:01   *                                                   *           (916) 551-1748
 *                                       *                                                   *
 *****************************************                                                   ********************************




                                                 X     X  XXXXXXX   XXXXX           X
                                                 X     X  X        X     X         XX
                                                 X     X  X        X                X
                                                 XXXXXXX  XXXX     X        XXXXX   X
                                                 X     X  X        X                X
                                                 X     X  X        X     X          X
                                                 X     X  XXXXXXX   XXXXX          XXX




            THIS PROGRAM REPLACES ALL PREVIOUS VERSIONS OF HEC-1 KNOWN AS HEC1 (JAN 73), HEC1GS, HEC1DB, AND HEC1KW.

            THE DEFINITIONS OF VARIABLES -RTIMP- AND -RTIOR- HAVE CHANGED FROM THOSE USED WITH THE 1973-STYLE INPUT STRUCTURE
            THE DEFINITION OF -AMSKK- ON RM-CARD WAS CHANGED WITH REVISIONS DATED 28 SEP 81. THIS IS THE FORTRAN77 VERSION
            NEW OPTIONS: DAMBREAK OUTFLOW SUBMERGENCE , SINGLE EVENT DAMAGE CALCULATION, DSS:WRITE STAGE FREQUENCY,
            DSS:READ TIME SERIES AT DESIRED CALCULATION INTERVAL   LOSS RATE:GREEN AND AMPT INFILTRATION
            KINEMATIC WAVE: NEW FINITE DIFFERENCE ALGORITHM


1                                                       HEC-1 INPUT                                             PAGE  1

           LINE           ID.......1.......2.......3.......4.......5.......6.......7.......8.......9......10

               1          ID        BROADMOOR RESORT COMMUNITY (SOUTH) MASTER DRAINAGE PLAN
               2          ID        100-YR,2-HR    EXISTING
               3          ID        MODIFICATION OF FLO ENGINEERING,INC STUDY/FULL BASIN
                          *DIAGRAM
               4          IT       1 22SEP97    1200    1500
               5          IN       5
               6          IO       5       0

               7          KK   B12-1
               8          KM        RUNOFF FROM SDA 12-1
               9          BA    .089
              10          PB     3.1
              11          PI     .01     .03     .04     .07     .12     .22     .12     .07     .05     .04
              12          PI     .03     .03     .03     .02     .02     .01     .01     .01     .01     .01
              13          PI     .01     .01     .01     .01
              14          LS       0      76       6
              15          UD    .126

              16          KK   B12-2
              17          KM        RUNOFF FROM SDA 12-2
              18          BA    .028
              19          LS       0      76       6
              20          UD    .113

              21          KK     DP1
              22          KM        COMBINE FLOWS FROM SDAs 12-1, 12-2
              23          HC       2

              24          KK     A-A
              25          KM        ROUTE FLOWS FROM CP1 TO CP2
              26          RS       1    STOR       0
              27          RC    0.12     .08    0.12     630    0.24
              28          RX       0       5      10      20      28      38      43      48
              29          RY      15    12.5      10       0       0      10    12.5      15

              30          KK   B12-3
              31          KM        RUNOFF FROM SDA 12-3
              32          BA    .027
              33          LS       0      76       6
              34          UD    .145

              35          KK   B12-4
              36          KM        RUNOFF FROM SDA 12-4
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```
           37          BA    .038
           38          LS       0      75       6
           39          UD    .110

           40          KK   B12-7
           41          KM        RUNOFF FROM SDA 12-7
           42          BA    .016
           43          LS       0      75       5
           44          UD    .134
1                                                     HEC-1 INPUT                                           PAGE  2

          LINE          ID.......1.......2.......3.......4.......5.......6.......7.......8.......9......10


           45          KK     DP2
           46          KM        COMBINE CP1 & SDAs 12-3, 12-4, 12-7
           47          HC       4

           48          KK     B-B
           49          KM        ROUTE FLOWS FROM CP2 TO CP3
           50          RS       1    STOR       0
           51          RC    0.12     .08    0.12     790    0.19
           52          RX       0       5      10      20      28      38      43      48
           53          RY      15    12.5      10       0       0      10    12.5      15

           54          KK   B12-5
           55          KM        RUNOFF FROM SDA 12-5
           56          BA    .081
           57          LS       0      76      10
           58          UD    .154

           59          KK   B12-8
           60          KM        RUNOFF FROM SDA 12-8
           61          BA    .023
           62          LS       0      75       5
           63          UD    .077

           64          KK     DP3
           65          KM        COMBINE FLOWS FROM CP2 & SDAs 12-5, 12-8
           66          HC       3

           67          KK     C-C
           68          KM        ROUTE FLOW FROM CP3 TO CP4
           69          RS       1    STOR       0
           70          RC    0.12     .08    0.12     650    0.26
           71          RX       0       5      10      20      28      38      43      48
           72          RY      15    12.5      10       0       0      10    12.5      15

           73          KK   B12-6
           74          KM        RUNOFF FROM SDA 12-6
           75          BA    .061
           76          LS       0      76      10
           77          UD    .129

           78          KK   B12-9
           79          KM        RUNOFF FROM SDA 12-9
           80          BA    .021
           81          LS       0      75       4
           82          UD    .112

           83          KK     DP4
           84          KM        COMBINE FLOWS FROM CP3 & SDAs 12-6, 12-9
           85          HC       3
1                                                     HEC-1 INPUT                                           PAGE  3

          LINE          ID.......1.......2.......3.......4.......5.......6.......7.......8.......9......10


           86          KK     D-D
           87          KM        ROUTE FLOWS FROM CP4 TO CP5
           88          RS       1    STOR       0
           89          RC    0.12     .08    0.12    1420    0.19
           90          RX       0       5      10      20      28      38      43      48
           91          RY      15    12.5      10       0       0      10    12.5      15

           92          KK   B1210
           93          KM        RUNOFF FROM SDA 12-10
           94          BA    .069
           95          LS       0      75       5
           96          UD    .170
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  97           KK     DP5
  98           KM        COMBINE FLOWS FROM CP4 & SDA 1210
  99           HC        2

 100           KK     E-E
 101           KM        ROUTE FLOW FROM CP5 TO CP6
 102           RS        1    STOR       0
 103           RC     0.12     .08    0.12    1420     0.11
 104           RX        0       5      10      20       28      38      43      48
 105           RY       15    12.5      10       0        0      10    12.5      15

 106           KK   B1211
 107           KM        RUNOFF FROM SDA 12-11
 108           BA     .041
 109           LS        0      74      10
 110           UD     .073

 111           KK     DP6
 112           KM        COMBINE DP5 & 1211
 113           HC        2

 114           KK     F-F
 115           KM        ROUTE FLOW FROM 12-11 TO 1011-1
 116           RS        1    STOR       0
 117           RC     0.12     .08    0.12    1200      .13
 118           RX        0       5      10      20       28      38      43      48
 119           RY       15    12.5      10       0        0      10    12.5      15

 120           KK  B10111
 121           KM        RUNOFF FROM SDA 1011-1
 122           BA     .035
 123           LS        0      74       7
 124           UD     .160

 125           KK  B10112
 126           KM        RUNOFF FROM SDA 1011-2
 127           BA     .037
 128           LS        0      74       7
 129           UD     .160
1                                            HEC-1 INPUT                                        PAGE  4

LINE           ID.......1.......2.......3.......4.......5.......6.......7.......8.......9......10


 130           KK     DP8
 131           KM        COMBINE FLOW FROM SDA 1012 & CP6A
 132           HC        3

 133           KK     G-G
 134           KM        ROUTE FLOW FROM DP8 TO DP300
 135           RS        1    STOR       0
 136           RC     0.12     .08    0.12    1200      .12
 137           RX        0       5      10      20       28      38      43      48
 138           RY       15    12.5      10       0        0      10    12.5      15

 139           KK    300A
 140           KM        RUNOFF FROM 300A
 141           BA     .049
 142           LS        0      58       4
 143           UD     .313

 144           KK   DP300
 145           KM        COMBINE FLOWS FROM CP8 & SDA 300A
 146           HC        2

 147           KK      B9
 148           KM        RUNOFF FROM SDA 9
 149           BA     .085
 150           LS        0      74       4
 151           UD     .125

 152           KK     H-H
 153           KM        ROUTE FLOW FROM B9 THRU SDA 300B
 154           RS        1    STOR       0
 155           RC     0.12     .08    0.12    1200      .25
 156           RX        0       5      10      20       28      38      43      48
 157           RY       15    12.5      10       0        0      10    12.5      15

 158           KK    300B
 159           KM        RUNOFF FROM 300B
 160           BA     .026
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          161            LS        0       58        4
          162            UD     .247

          163            KK      DP9
          164            KM          COMBINE SDA B9 & 300B
          165            HC        2

          166            KK    DP301
          167            KM          COMBINE FLOWS FROM CP300 & SDA 300B
          168            HC        2

          169            KK      I-I
          170            KM          ROUTE FLOW FROM B9 THRU SDA 300B
          171            RS        1     STOR        0
          172            RC     0.12      .08     0.12     1800      .17
          173            RX        0        4      5.5      6.5     14.5     15.5       17       21
          174            RY        7        5        2        0        0        2        5        7
1                                                      HEC-1 INPUT                                          PAGE  5

         LINE            ID.......1.......2.......3.......4.......5.......6.......7.......8.......9......10


          175            KK     300C
          176            KM          RUNOFF FROM SDA 300C
          177            BA      .06
          178            LS        0       58        4
          179            UD     .288

          180            KK    DP302
          181            KM          COMBINE FLOWS FROM CP301 & 300C
          182            HC        2

          183            KK     100A
          184            KM          RUNOFF FROM SDA 100A
          185            BA     .048
          186            LS        0       58        4
          187            UD     .271

          188            KK     100B
          189            KM          RUNOFF FROM SDA 100B
          190            BA     .022
          191            LS        0       58        4
          192            UD     .260

          193            KK    DP101
          194            KM          COMBINE FLOWS FROM CP100 & SDA 100B
          195            HC        2

          196            KK     100C
          197            KM          RUNOFF FROM SDA 100C
          198            BA     .035
          199            LS        0       58        4
          200            UD     .292

          201            KK    DP102
          202            KM          COMBINE FLOWS FROM CP101 & SDA 100C
          203            HC        2

          204            KK     200A
          205            KM          RUNOFF FROM 200A
          206            BA     .035
          207            LS        0       58        4
          208            UD     .281

          209            KK     200C
          210            KM          RUNOFF FROM 200C
          211            BA     .051
          212            LS        0       58        4
          213            UD     .281

          214            KK    DP200
          215            KM          COMBINE FLOWS FROM SDAs 200A & 200C
          216            HC        2
1                                                      HEC-1 INPUT                                          PAGE  6

         LINE            ID.......1.......2.......3.......4.......5.......6.......7.......8.......9......10


          217            KK     200B
          218            KM          RUNOFF FROM 200B
          219            BA     .017
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```
        220          LS       0       58        4
        221          UD    .281

        222          KK     B34
        223          KM        RUNOFF FROM SDA       34
        224          BA    .023
        225          LS       0       74        7
        226          UD    .125

        227          KK     J-J
        228          KM        ROUTE FLOW FROM B3 THRU 500C
        229          RS       1     STOR        0
        230          RC    0.12      .08     0.12     1500      .21
        231          RX       0        5       10       20       28       38       43       48
        232          RY      15     12.5       10        0        0       10     12.5       15

        233          KK    500C
        234          KM         RUNOFF FROM 500C
        235          BA    .015
        236          LS       0       58        4
        237          UD    .208

        238          KK   DP345
        239          KM        COMBINE SDAs 34 & 500C
        240          HC       2

        241          KK      B5
        242          KM        RUNOFF FROM SDA 5
        243          BA    .042
        244          LS       0       74        7
        245          UD    .131

        246          KK      B6
        247          KM        RUNOFF FROM SDA 6
        248          BA    .022
        249          LS       0       74        7
        250          UD    .131

        251          KK    DP56
        252          KM        COMBINE FLOWS FROM SDAs 5&6
        253          HC       2

        254          KK     K-K
        255          KM        ROUTE FLOW FROM DP 56 THRU 500A
        256          RS       1     STOR        0
        257          RC    0.12      .08     0.12     2100      .22
        258          RX       0        5       10       20       28       38       43       48
        259          RY      15     12.5       10        0        0       10     12.5       15
1                                                      HEC-1 INPUT                                         PAGE  7

       LINE          ID.......1.......2.......3.......4.......5.......6.......7.......8.......9......10


        260          KK    500A
        261          KM        RUNOFF FROM SDA 500A
        262          BA    .036
        263          LS       0       58        4
        264          UD    .313

        265          KK   DP500
        266          KM        COMBINE FLOWS FROM CP56&500A
        267          HC       3

        268          KK    500B
        269          KM        RUNOFF FROM SDA 500B
        270          BA    .009
        271          LS       0       58        4
        272          UD    .208

        273          KK   DP501
        274          KM        COMBINE FLOWS FROM CP5A&500B
        275          HC       2

        276          KK      B7
        277          KM        RUNOFF FROM SDA 7
        278          BA    .014
        279          LS       0       74        7
        280          UD    .107

        281          KK    B8-1
        282          KM        RUNOFF FROM SDA 8-1
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         283            BA    .056
         284            LS      0      74       7
         285            UD    .113

         286            KK    B8-2
         287            KM       RUNOFF FROM SDA 8-2
         288            BA    .016
         289            LS      0      74       7
         290            UD    .086

         291            KK     DP7
         292            KM       COMBINE FLOWS FROM SDAs 8-1, 8-2
         293            HC      2

         294            KK    B8-3
         295            KM       RUNOFF FROM SDA 8-3
         296            BA    .021
         297            LS      0      74       7
         298            UD    .202

         299            KK    DP7A
         300            KM       COMBINE FLOW FROM CP7 & SDA 8-3 &B7
         301            HC      3
1                                              HEC-1 INPUT                                         PAGE  8

        LINE            ID.......1.......2.......3.......4.......5.......6.......7.......8.......9......10


         302            KK    400A
         303            KM       RUNOFF FROM SDA     400A
         304            BA     .02
         305            LS      0      58       4
         306            UD    .506

         307            KK   DP401
         308            KM       COMBINE FLOWS FROM DP7A & SDA 400A
         309            HC      2

         310            KK    400B
         311            KM       RUNOFF FROM SDA     400B
         312            BA     .01
         313            LS      0      58       4
         314            UD    .406

         315            KK   DP402
         316            KM       COMBINE FLOWS FROM DP402& SDA 400B
         317            HC      2
         318            ZZ
1
               SCHEMATIC DIAGRAM OF STREAM NETWORK
 INPUT
  LINE      (V) ROUTING          (--->) DIVERSION OR PUMP FLOW

   NO.      (.) CONNECTOR        (<---) RETURN OF DIVERTED OR PUMPED FLOW

     7       B12-1
                .
                .
    16          .       B12-2
                .           .
                .           .
    21        DP1............
                V
                V
    24        A-A
                .
                .
    30          .       B12-3
                .           .
                .           .
    35          .           .       B12-4
                .           .           .
                .           .           .
    40          .           .           .       B12-7
                .           .           .           .
                .           .           .           .
    45        DP2.................................
                V
                V
    48        B-B
                .
```

```
              .
54            .       B12-5
              .           .
              .           .
59            .           .       B12-8
              .           .           .
              .           .           .
64          DP3........................
              V
              V
67          C-C
              .
              .
73            .       B12-6
              .           .
              .           .
78            .           .       B12-9
              .           .           .
              .           .           .
83          DP4........................
              V
              V
86          D-D
              .
              .
92            .       B1210
              .           .
              .           .
97          DP5............
              V
              V
100         E-E
              .
              .
106           .       B1211
              .           .
              .           .
111         DP6............
              V
              V
114         F-F
              .
              .
120           .      B10111
              .           .
              .           .
125           .           .     B10112
              .           .           .
              .           .           .
130         DP8........................
              V
              V
133         G-G
              .
              .
139           .        300A
              .           .
              .           .
144       DP300............
              .
              .
147           .          B9
              .           V
              .           V
152           .         H-H
              .           .
              .           .
158           .           .       300B
              .           .           .
              .           .           .
163           .         DP9............
              .           .
              .           .
166       DP301............
              V
              V
169         I-I
              .
              .
175           .        300C
              .           .
```

```
              .           .
180       DP302............
              .
              .
183           .        100A
              .           .
              .           .
188           .           .        100B
              .           .           .
              .           .           .
193           .       DP101............
              .           .
              .           .
196           .           .        100C
              .           .           .
              .           .           .
201           .       DP102............
              .           .
              .           .
204           .           .        200A
              .           .           .
              .           .           .
209           .           .           .        200C
              .           .           .           .
              .           .           .           .
214           .           .       DP200............
              .           .           .
              .           .           .
217           .           .           .        200B
              .           .           .           .
              .           .           .           .
222           .           .           .           .         B34
              .           .           .           .           V
              .           .           .           .           V
227           .           .           .           .         J-J
              .           .           .           .           .
              .           .           .           .           .
233           .           .           .           .           .        500C
              .           .           .           .           .           .
              .           .           .           .           .           .
238           .           .           .           .       DP345............
              .           .           .           .           .
              .           .           .           .           .
241           .           .           .           .           .          B5
              .           .           .           .           .           .
              .           .           .           .           .           .
246           .           .           .           .           .           .          B6
              .           .           .           .           .           .           .
              .           .           .           .           .           .           .
251           .           .           .           .           .        DP56............
              .           .           .           .           .           V
              .           .           .           .           .           V
254           .           .           .           .           .         K-K
              .           .           .           .           .           .
              .           .           .           .           .           .
260           .           .           .           .           .           .        500A
              .           .           .           .           .           .           .
              .           .           .           .           .           .           .
265           .           .           .           .       DP500........................
              .           .           .           .           .
              .           .           .           .           .
268           .           .           .           .           .        500B
              .           .           .           .           .           .
              .           .           .           .           .           .
273           .           .           .           .       DP501............
              .           .           .           .           .
              .           .           .           .           .
276           .           .           .           .           .          B7
              .           .           .           .           .           .
              .           .           .           .           .           .
281           .           .           .           .           .           .        B8-1
              .           .           .           .           .           .           .
              .           .           .           .           .           .           .
286           .           .           .           .           .           .           .        B8-2
              .           .           .           .           .           .           .           .
              .           .           .           .           .           .           .           .
291           .           .           .           .           .           .         DP7............
              .           .           .           .           .           .           .
              .           .           .           .           .           .           .
294           .           .           .           .           .           .           .        B8-3
              .           .           .           .           .           .           .           .
```

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             .           .           .           .           .           .           .           .
   299       .           .           .           .           .         DP7A.......................
             .           .           .           .           .           .
             .           .           .           .           .           .
   302       .           .           .           .           .           .         400A
             .           .           .           .           .           .           .
             .           .           .           .           .           .           .
   307       .           .           .           .           .        DP401...........
             .           .           .           .           .           .
             .           .           .           .           .           .
   310       .           .           .           .           .           .         400B
             .           .           .           .           .           .           .
             .           .           .           .           .           .           .
   315       .           .           .           .           .        DP402...........

(***) RUNOFF ALSO COMPUTED AT THIS LOCATION
1****************************************                                                  *******************************
 *                                       *                                                  *
 *   FLOOD HYDROGRAPH PACKAGE  (HEC-1)   *                                                  *   U.S. ARMY CORPS OF ENGINEER
 *              JUN 09 1992              *                                                  *   HYDROLOGIC ENGINEERING CENT
 *            VERSION 4.0.3E             *                                                  *        609 SECOND STREET
 *                                       *                                                  *     DAVIS, CALIFORNIA 95616
 *  RUN DATE  12/02/97  TIME  11:40:01   *                                                  *        (916) 551-1748
 *                                       *                                                  *
****************************************                                                   *******************************




                                        BROADMOOR RESORT COMMUNITY (SOUTH) MASTER DRAINAGE PLAN
                                        100-YR,2-HR     EXISTING
                                        MODIFICATION OF FLO ENGINEERING,INC STUDY/FULL BASIN

    6 IO         OUTPUT CONTROL VARIABLES
                       IPRNT           5  PRINT CONTROL
                       IPLOT           0  PLOT CONTROL
                       QSCAL          0.  HYDROGRAPH PLOT SCALE

      IT         HYDROGRAPH TIME DATA
                        NMIN           1  MINUTES IN COMPUTATION INTERVAL
                       IDATE     22SEP97  STARTING DATE
                       ITIME        1200  STARTING TIME
                          NQ        1500  NUMBER OF HYDROGRAPH ORDINATES
                      NDDATE     23SEP97  ENDING DATE
                      NDTIME        1259  ENDING TIME
                       ICENT          19  CENTURY MARK

                   COMPUTATION INTERVAL    0.02 HOURS
                        TOTAL TIME BASE   24.98 HOURS

          ENGLISH UNITS
               DRAINAGE AREA          SQUARE MILES
               PRECIPITATION DEPTH    INCHES
               LENGTH, ELEVATION      FEET
               FLOW                   CUBIC FEET PER SECOND
               STORAGE VOLUME         ACRE-FEET
               SURFACE AREA           ACRES
               TEMPERATURE            DEGREES FAHRENHEIT
1
                                                                  RUNOFF SUMMARY
                                                          FLOW IN CUBIC FEET PER SECOND
                                                       TIME IN HOURS,  AREA IN SQUARE MILES

                                              PEAK    TIME OF      AVERAGE FLOW FOR MAXIMUM PERIOD       BASIN     MAXIMUM     TIME OF
                OPERATION       STATION       FLOW     PEAK                                               AREA      STAGE     MAX STAGE
+                                                                  6-HOUR      24-HOUR      72-HOUR

                HYDROGRAPH AT
+                                 B12-1        112.    0.65          12.          3.           3.        0.09

                HYDROGRAPH AT
+                                 B12-2         37.    0.63           4.          1.           1.        0.03

                2 COMBINED AT
+                                   DP1        148.    0.65          15.          4.           4.        0.12

                ROUTED TO
+                                   A-A        148.    0.67          15.          4.           4.        0.12
+                                                                                                                    1.51        0.67
```

```
              HYDROGRAPH AT
+                            B12-3       32.    0.68          3.         1.         1.      0.03

              HYDROGRAPH AT
+                            B12-4       47.    0.63          5.         1.         1.      0.04

              HYDROGRAPH AT
+                            B12-7       18.    0.67          2.         0.         0.      0.02

              4 COMBINED AT
+                              DP2      244.    0.67         25.         6.         6.      0.20

              ROUTED TO
+                              B-B      242.    0.68         25.         6.         6.      0.20
+                                                                                                      2.15        0.68

              HYDROGRAPH AT
+                            B12-5      102.    0.68         11.         3.         3.      0.08

              HYDROGRAPH AT
+                            B12-8       31.    0.60          3.         1.         1.      0.02

              3 COMBINED AT
+                              DP3      369.    0.67         39.        10.         9.      0.30

              ROUTED TO
+                              C-C      369.    0.68         39.        10.         9.      0.30
+                                                                                                      2.52        0.68

              HYDROGRAPH AT
+                            B12-6       82.    0.65          8.         2.         2.      0.06

              HYDROGRAPH AT
+                            B12-9       25.    0.65          3.         1.         1.      0.02

              3 COMBINED AT
+                              DP4      472.    0.68         50.        13.        12.      0.38

              ROUTED TO
+                              D-D      466.    0.70         50.        13.        12.      0.38
+                                                                                                      3.16        0.70

              HYDROGRAPH AT
+                            B1210       72.    0.72          8.         2.         2.      0.07

              2 COMBINED AT
+                              DP5      537.    0.70         59.        15.        14.      0.45

              ROUTED TO
+                              E-E      527.    0.73         59.        15.        14.      0.45
+                                                                                                      3.93        0.73

              HYDROGRAPH AT
+                            B1211       57.    0.58          5.         1.         1.      0.04

              2 COMBINED AT
+                              DP6      564.    0.73         64.        16.        15.      0.49

              ROUTED TO
+                              F-F      558.    0.75         64.        16.        15.      0.49
+                                                                                                      3.87        0.75

              HYDROGRAPH AT
+                           B10111       37.    0.70          4.         1.         1.      0.04

              HYDROGRAPH AT
+                           B10112       39.    0.70          4.         1.         1.      0.04

              3 COMBINED AT
+                              DP8      630.    0.75         73.        18.        17.      0.57

              ROUTED TO
+                              G-G      624.    0.77         73.        18.        17.      0.57
+                                                                                                      4.19        0.77

              HYDROGRAPH AT
+                             300A       11.    1.02          2.         1.         1.      0.05

              2 COMBINED AT
+                            DP300      632.    0.77         75.        19.        18.      0.62
```

```
           HYDROGRAPH AT
+                           B9      91.   0.67        10.       2.        2.     0.09
           ROUTED TO
+                          H-H      89.   0.68        10.       2.        2.     0.09
+                                                                                         1.07      0.68
           HYDROGRAPH AT
+                         300B       6.   0.92         1.       0.        0.     0.03
           2 COMBINED AT
+                          DP9      93.   0.70        11.       3.        3.     0.11
           2 COMBINED AT
+                        DP301     718.   0.77        86.      21.       21.     0.73
           ROUTED TO
+                          I-I     710.   0.78        86.      21.       21.     0.73
+                                                                                         4.31      0.78
           HYDROGRAPH AT
+                         300C      14.   0.98         3.       1.        1.     0.06
           2 COMBINED AT
+                        DP302     721.   0.78        88.      22.       21.     0.79
           HYDROGRAPH AT
+                         100A      11.   0.95         2.       1.        1.     0.05
           HYDROGRAPH AT
+                         100B       5.   0.95         1.       0.        0.     0.02
           2 COMBINED AT
+                        DP101      17.   0.95         3.       1.        1.     0.07
           HYDROGRAPH AT
+                         100C       8.   0.98         2.       0.        0.     0.04
           2 COMBINED AT
+                        DP102      25.   0.97         5.       1.        1.     0.11
           HYDROGRAPH AT
+                         200A       8.   0.97         2.       0.        0.     0.04
           HYDROGRAPH AT
+                         200C      12.   0.97         2.       1.        1.     0.05
           2 COMBINED AT
+                        DP200      20.   0.97         4.       1.        1.     0.09
           HYDROGRAPH AT
+                         200B       4.   0.97         1.       0.        0.     0.02
           HYDROGRAPH AT
+                          B34      26.   0.65         3.       1.        1.     0.02
           ROUTED TO
+                          J-J      24.   0.73         3.       1.        1.     0.02
+                                                                                         0.41      0.73
           HYDROGRAPH AT
+                         500C       4.   0.87         1.       0.        0.     0.01
           2 COMBINED AT
+                        DP345      27.   0.73         3.       1.        1.     0.04
           HYDROGRAPH AT
+                           B5      47.   0.67         5.       1.        1.     0.04
           HYDROGRAPH AT
+                           B6      25.   0.67         3.       1.        1.     0.02
           2 COMBINED AT
+                         DP56      72.   0.67         8.       2.        2.     0.06
           ROUTED TO
+                          K-K      66.   0.73         8.       2.        2.     0.06
+                                                                                         0.94      0.73
           HYDROGRAPH AT
+                         500A       8.   1.02         2.       0.        0.     0.04
```

```
           3 COMBINED AT
+                          DP500        98.    0.73          13.         3.         3.      0.14

           HYDROGRAPH AT
+                           500B         2.    0.87           0.         0.         0.      0.01

           2 COMBINED AT
+                          DP501       100.    0.73          13.         3.         3.      0.15

           HYDROGRAPH AT
+                             B7        17.    0.63           2.         0.         0.      0.01

           HYDROGRAPH AT
+                           B8-1        66.    0.65           7.         2.         2.      0.06

           HYDROGRAPH AT
+                           B8-2        20.    0.60           2.         0.         0.      0.02

           2 COMBINED AT
+                            DP7        86.    0.63           9.         2.         2.      0.07

           HYDROGRAPH AT
+                           B8-3        20.    0.77           3.         1.         1.      0.02

           3 COMBINED AT
+                           DP7A       117.    0.65          13.         3.         3.      0.11

           HYDROGRAPH AT
+                           400A         4.    1.32           1.         0.         0.      0.02

           2 COMBINED AT
+                          DP401       118.    0.65          14.         3.         3.      0.13

           HYDROGRAPH AT
+                           400B         2.    1.17           0.         0.         0.      0.01

           2 COMBINED AT
+                          DP402       119.    0.65          14.         4.         3.      0.14


 *** NORMAL END OF HEC-1 ***
```

```
1*****************************************                                                ***********************************
 *                                       *                                                *
 *   FLOOD HYDROGRAPH PACKAGE  (HEC-1)   *                                                *   U.S. ARMY CORPS OF ENGINEER
 *             JUN 09 1992               *                                                *   HYDROLOGIC ENGINEERING CENT
 *           VERSION 4.0.3E              *                                                *         609 SECOND STREET
 *                                       *                                                *      DAVIS, CALIFORNIA 95616
 * RUN DATE  02/13/98  TIME  15:50:30    *                                                *          (916) 551-1748
 *                                       *                                                *
 *****************************************                                                ***********************************




                                             X     X  XXXXXXX   XXXXX           X
                                             X     X  X        X     X         XX
                                             X     X  X        X                X
                                             XXXXXXX  XXXX     X        XXXXX   X
                                             X     X  X        X                X
                                             X     X  X        X     X          X
                                             X     X  XXXXXXX   XXXXX          XXX




               THIS PROGRAM REPLACES ALL PREVIOUS VERSIONS OF HEC-1 KNOWN AS HEC1 (JAN 73), HEC1GS, HEC1DB, AND HEC1KW.

               THE DEFINITIONS OF VARIABLES -RTIMP- AND -RTIOR- HAVE CHANGED FROM THOSE USED WITH THE 1973-STYLE INPUT STRUCTURE
               THE DEFINITION OF -AMSKK- ON RM-CARD WAS CHANGED WITH REVISIONS DATED 28 SEP 81. THIS IS THE FORTRAN77 VERSION
               NEW OPTIONS: DAMBREAK OUTFLOW SUBMERGENCE , SINGLE EVENT DAMAGE CALCULATION, DSS:WRITE STAGE FREQUENCY,
               DSS:READ TIME SERIES AT DESIRED CALCULATION INTERVAL   LOSS RATE:GREEN AND AMPT INFILTRATION
               KINEMATIC WAVE: NEW FINITE DIFFERENCE ALGORITHM


1                                                 HEC-1 INPUT                                                   PAGE  1

              LINE          ID.......1.......2.......3.......4.......5.......6.......7.......8.......9......10

                 1          ID        BROADMOOR RESORT COMMUNITY (SOUTH) MASTER DRAINAGE PLAN
                 2          ID        5-YR, 2-HR      DEVELOPED
                 3          ID        MODIFICATION OF FLO ENGINEERING,INC STUDY/FULL BASIN
                            *DIAGRAM
                 4          IT       1 22SEP97    1200    1500
                 5          IN       5
                 6          IO       5       0

                 7          KK   B12-1
                 8          KM        RUNOFF FROM SDA 12-1
                 9          BA    .089
                10          PB     1.6
                11          PI     .01     .03     .04     .07     .12     .22     .12     .07     .05     .04
                12          PI     .03     .03     .03     .02     .02     .01     .01     .01     .01     .01
                13          PI     .01     .01     .01     .01
                14          LS       0      76       6
                15          UD    .126

                16          KK   B12-2
                17          KM        RUNOFF FROM SDA 12-2
                18          BA    .028
                19          LS       0      76       6
                20          UD    .113

                21          KK     DP1
                22          KM        COMBINE FLOWS FROM SDAs 12-1, 12-2
                23          HC       2

                24          KK     A-A
                25          KM        ROUTE FLOWS FROM CP1 TO CP2
                26          RS       1    STOR       0
                27          RC    0.12     .08    0.12     630    0.24
                28          RX       0       5      10      20      28      38      43      48
                29          RY      15    12.5      10       0       0      10    12.5      15

                30          KK   B12-3
                31          KM        RUNOFF FROM SDA 12-3
                32          BA    .027
                33          LS       0      76       6
                34          UD    .145

                35          KK   B12-4
                36          KM        RUNOFF FROM SDA 12-4
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        37          BA    .038
        38          LS      0      75       6
        39          UD    .110

        40          KK   B12-7
        41          KM       RUNOFF FROM SDA 12-7
        42          BA    .016
        43          LS      0      75       5
        44          UD    .134
1                                      HEC-1 INPUT                                         PAGE  2

      LINE          ID.......1.......2.......3.......4.......5.......6.......7.......8.......9......10


        45          KK     DP2
        46          KM       COMBINE CP1 & SDAs 12-3, 12-4, 12-7
        47          HC       4

        48          KK     B-B
        49          KM       ROUTE FLOWS FROM CP2 TO CP3
        50          RS       1    STOR       0
        51          RC    0.12     .08    0.12     790    0.19
        52          RX       0       5      10      20      28      38      43      48
        53          RY      15    12.5      10       0       0      10    12.5      15

        54          KK   B12-5
        55          KM       RUNOFF FROM SDA 12-5
        56          BA    .081
        57          LS      0      76      10
        58          UD    .154

        59          KK   B12-8
        60          KM       RUNOFF FROM SDA 12-8
        61          BA    .023
        62          LS      0      75       5
        63          UD    .077

        64          KK     DP3
        65          KM       COMBINE FLOWS FROM CP2 & SDAs 12-5, 12-8
        66          HC       3

        67          KK     C-C
        68          KM       ROUTE FLOW FROM CP3 TO CP4
        69          RS       1    STOR       0
        70          RC    0.12     .08    0.12     650    0.26
        71          RX       0       5      10      20      28      38      43      48
        72          RY      15    12.5      10       0       0      10    12.5      15

        73          KK   B12-6
        74          KM       RUNOFF FROM SDA 12-6
        75          BA    .061
        76          LS      0      76      10
        77          UD    .129

        78          KK   B12-9
        79          KM       RUNOFF FROM SDA 12-9
        80          BA    .021
        81          LS      0      75       4
        82          UD    .112

        83          KK     DP4
        84          KM       COMBINE FLOWS FROM CP3 & SDAs 12-6, 12-9
        85          HC       3
1                                      HEC-1 INPUT                                         PAGE  3

      LINE          ID.......1.......2.......3.......4.......5.......6.......7.......8.......9......10


        86          KK     D-D
        87          KM       ROUTE FLOWS FROM CP4 TO CP5
        88          RS       1    STOR       0
        89          RC    0.12     .08    0.12    1420    0.19
        90          RX       0       5      10      20      28      38      43      48
        91          RY      15    12.5      10       0       0      10    12.5      15

        92          KK   B1210
        93          KM       RUNOFF FROM SDA 12-10
        94          BA    .069
        95          LS      0      75       5
        96          UD    .170
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   97           KK     DP5
   98           KM        COMBINE FLOWS FROM CP4 & SDA 1210
   99           HC        2

  100           KK     E-E
  101           KM        ROUTE FLOW FROM CP5 TO CP6
  102           RS        1    STOR       0
  103           RC     0.12     .08    0.12    1420    0.11
  104           RX        0       5      10      20      28      38      43      48
  105           RY       15    12.5      10       0       0      10    12.5      15

  106           KK     DAM
  107           KM        ROUTE FLOW THROUGH FISHERS CNAYON DEBRIS CONTROL STURCTURE
  108           RS        1    ELEV    7155
  109           SV        0     0.3    0.75    1.35    2.55     3.6     3.8     6.1     8.5    11.0
  110           SV     13.5    16.1    18.8
  111           SE     7155    7160    7165    7170    7175    7178    7180    7182    7184    7186
  112           SE     7188    7190    7192
  113           SQ        0      19      39      51      61      67      70     158     197     227
  114           SQ     1853    4801    8610

  115           KK   B1211
  116           KM        RUNOFF FROM SDA 12-11
  117           BA     .041
  118           LS        0      74      10
  119           UD     .073

  120           KK     DP6
  121           KM        COMBINE DP5 & 1211
  122           HC        2

  123           KK     F-F
  124           KM        ROUTE FLOW FROM 12-11 TO 1011-1
  125           RS        1    STOR       0
  126           RC     0.12     .08    0.12    1200     .13
  127           RX        0       5      10      20      28      38      43      48
  128           RY       15    12.5      10       0       0      10    12.5      15
1                                              HEC-1 INPUT                                              PAGE  4

 LINE           ID.......1.......2.......3.......4.......5.......6.......7.......8.......9......10


  129           KK  B10111
  130           KM        RUNOFF FROM SDA 1011-1
  131           BA     .035
  132           LS        0      74       7
  133           UD     .160

  134           KK  B10112
  135           KM        RUNOFF FROM SDA 1011-2
  136           BA     .037
  137           LS        0      74       7
  138           UD     .160

  139           KK     DP8
  140           KM        COMBINE FLOW FROM SDA 1012 & CP6A
  141           HC        3

  142           KK     G-G
  143           KM        ROUTE FLOW FROM DP8 TO DP300
  144           RS        1    STOR       0
  145           RC     0.12     .08    0.12    1200     .12
  146           RX        0       5      10      20      28      38      43      48
  147           RY       15    12.5      10       0       0      10    12.5      15

  148           KK    300A
  149           KM        RUNOFF FROM 300A
  150           BA     .049
  151           LS        0      65       4
  152           UD     .162

  153           KK   DP300
  154           KM        COMBINE FLOWS FROM CP8 & SDA 300A
  155           HC        2

  156           KK      B9
  157           KM        RUNOFF FROM SDA 9
  158           BA     .085
  159           LS        0      74       4
  160           UD     .125
```

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   161           KK      H-H
   162           KM         ROUTE FLOW FROM B9 THRU SDA 300B
   163           RS        1    STOR       0
   164           RC     0.12     .08    0.12    1200     .25
   165           RX        0       5      10      20      28      38      43      48
   166           RY       15    12.5      10       0       0      10    12.5      15

   167           KK     300B
   168           KM         RUNOFF FROM 300B
   169           BA     .026
   170           LS        0      68       4
   171           UD     .126
1                                             HEC-1 INPUT                                             PAGE  5

  LINE           ID.......1.......2.......3.......4.......5.......6.......7.......8.......9......10


   172           KK      DP9
   173           KM         COMBINE SDA B9 & 300B
   174           HC        2

   175           KK    DP301
   176           KM         COMBINE FLOWS FROM CP300 & SDA 300B
   177           HC        2

   178           KK      I-I
   179           KM         ROUTE FLOW FROM B9 THRU SDA 300B
   180           RS        1    STOR       0
   181           RC     0.12     .08    0.12    1800     .17
   182           RX        0       4     5.5     6.5    14.5    15.5      17      21
   183           RY        7       5       2       0       0       2       5       7

   184           KK     300C
   185           KM         RUNOFF FROM SDA 300C
   186           BA      .06
   187           LS        0      72       4
   188           UD     .150

   189           KK    DP302
   190           KM         COMBINE FLOWS FROM CP301 & 300C
   191           HC        2

   192           KK     100A
   193           KM         RUNOFF FROM SDA 100A
   194           BA     .048
   195           LS        0      66       4
   196           UD     .138

   197           KK     100B
   198           KM         RUNOFF FROM SDA 100B
   199           BA     .022
   200           LS        0      66       4
   201           UD     .132

   202           KK    DP101
   203           KM         COMBINE FLOWS FROM CP100 & SDA 100B
   204           HC        2

   205           KK     100C
   206           KM         RUNOFF FROM SDA 100C
   207           BA     .035
   208           LS        0      72       4
   209           UD     .150

   210           KK    DP102
   211           KM         COMBINE FLOWS FROM CP101 & SDA 100C
   212           HC        2
1                                             HEC-1 INPUT                                             PAGE  6

  LINE           ID.......1.......2.......3.......4.......5.......6.......7.......8.......9......10


   213           KK     200A
   214           KM         RUNOFF FROM 200A
   215           BA     .035
   216           LS        0      70       4
   217           UD     .144

   218           KK     200C
   219           KM         RUNOFF FROM 200C
   220           BA     .051
```

```
 221            LS      0      72       4
 222            UD    .144

 223            KK   DP200
 224            KM        COMBINE FLOWS FROM SDAs 200A & 200C
 225            HC      2

 226            KK    200B
 227            KM        RUNOFF FROM 200B
 228            BA    .017
 229            LS      0      72       4
 230            UD    .144

 231            KK     B34
 232            KM        RUNOFF FROM SDA       34
 233            BA    .023
 234            LS      0      74       7
 235            UD    .125

 236            KK     J-J
 237            KM        ROUTE FLOW FROM B3 THRU 500C
 238            RS      1    STOR       0
 239            RC   0.12     .08    0.12    1500     .21
 240            RX      0       5      10      20      28      38      43      48
 241            RY     15    12.5      10       0       0      10    12.5      15

 242            KK    500C
 243            KM         RUNOFF FROM 500C
 244            BA    .015
 245            LS      0      72       4
 246            UD    .108

 247            KK   DP345
 248            KM        COMBINE SDAs 34 & 500C
 249            HC      2

 250            KK      B5
 251            KM        RUNOFF FROM SDA 5
 252            BA    .042
 253            LS      0      74       7
 254            UD    .131
1                                        HEC-1 INPUT                                                PAGE  7

LINE            ID.......1.......2.......3.......4.......5.......6.......7.......8.......9......10


 255            KK      B6
 256            KM        RUNOFF FROM SDA 6
 257            BA    .022
 258            LS      0      74       7
 259            UD    .131

 260            KK    DP56
 261            KM        COMBINE FLOWS FROM SDAs 5&6
 262            HC      2

 263            KK     K-K
 264            KM        ROUTE FLOW FROM DP 56 THRU 500A
 265            RS      1    STOR       0
 266            RC   0.12     .08    0.12    2100     .22
 267            RX      0       5      10      20      28      38      43      48
 268            RY     15    12.5      10       0       0      10    12.5      15

 269            KK    500A
 270            KM        RUNOFF FROM SDA 500A
 271            BA    .036
 272            LS      0      72       4
 273            UD    .162

 274            KK   DP500
 275            KM        COMBINE FLOWS FROM CP56&500A
 276            HC      3

 277            KK    500B
 278            KM        RUNOFF FROM SDA 500B
 279            BA    .009
 280            LS      0      72       4
 281            UD    .108

 282            KK   DP501
 283            KM        COMBINE FLOWS FROM CP5A&500B
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         284          HC       2

         285          KK      B7
         286          KM         RUNOFF FROM SDA 7
         287          BA    .014
         288          LS       0      74       7
         289          UD    .107

         290          KK    B8-1
         291          KM         RUNOFF FROM SDA 8-1
         292          BA    .056
         293          LS       0      74       7
         294          UD    .113
1                                              HEC-1 INPUT                                     PAGE  8

        LINE          ID.......1.......2.......3.......4.......5.......6.......7.......8.......9......10


         295          KK    B8-2
         296          KM         RUNOFF FROM SDA 8-2
         297          BA    .016
         298          LS       0      74       7
         299          UD    .086

         300          KK     DP7
         301          KM         COMBINE FLOWS FROM SDAs 8-1, 8-2
         302          HC       2

         303          KK    B8-3
         304          KM         RUNOFF FROM SDA 8-3
         305          BA    .021
         306          LS       0      74       7
         307          UD    .202

         308          KK    DP7A
         309          KM         COMBINE FLOW FROM CP7 & SDA 8-3 &B7
         310          HC       3

         311          KK    400A
         312          KM         RUNOFF FROM SDA     400A
         313          BA     .02
         314          LS       0      72       4
         315          UD    .210

         316          KK   DP401
         317          KM         COMBINE FLOWS FROM DP7A & SDA 400A
         318          HC       2

         319          KK    400B
         320          KM         RUNOFF FROM SDA     400B
         321          BA     .01
         322          LS       0      72       4
         323          UD    .210

         324          KK   DP402
         325          KM         COMBINE FLOWS FROM DP402& SDA 400B
         326          HC       2
         327          ZZ
1
              SCHEMATIC DIAGRAM OF STREAM NETWORK
 INPUT
  LINE      (V) ROUTING          (--->) DIVERSION OR PUMP FLOW

  NO.       (.) CONNECTOR        (<---) RETURN OF DIVERTED OR PUMPED FLOW

    7        B12-1
               .
               .
   16          .         B12-2
               .             .
               .             .
   21         DP1............
               V
               V
   24         A-A
               .
               .
   30          .         B12-3
               .             .
               .             .
   35          .             .        B12-4
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             .           .           .
             .           .           .
40           .           .           .      B12-7
             .           .           .          .
             .           .           .          .
45         DP2...................................
             V
             V
48         B-B
             .
             .
54           .       B12-5
             .           .
             .           .
59           .           .       B12-8
             .           .           .
             .           .           .
64         DP3........................
             V
             V
67         C-C
             .
             .
73           .       B12-6
             .           .
             .           .
78           .           .       B12-9
             .           .           .
             .           .           .
83         DP4........................
             V
             V
86         D-D
             .
             .
92           .       B1210
             .           .
             .           .
97         DP5............
             V
             V
100        E-E
             V
             V
106        DAM
             .
             .
115          .       B1211
             .           .
             .           .
120        DP6............
             V
             V
123        F-F
             .
             .
129          .      B10111
             .           .
             .           .
134          .           .      B10112
             .           .           .
             .           .           .
139        DP8........................
             V
             V
142        G-G
             .
             .
148          .        300A
             .           .
             .           .
153      DP300............
             .
             .
156          .          B9
             .           V
             .           V
161          .         H-H
             .           .
             .           .
167          .           .        300B
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              .           .           .
              .           .           .
172           .         DP9............
              .           .
              .           .
175       DP301............
              V
              V
178         I-I
              .
              .
184           .        300C
              .           .
              .           .
189       DP302............
              .
              .
192           .        100A
              .           .
              .           .
197           .           .        100B
              .           .           .
              .           .           .
202           .       DP101............
              .           .
              .           .
205           .           .        100C
              .           .           .
              .           .           .
210           .       DP102............
              .           .
              .           .
213           .           .        200A
              .           .           .
              .           .           .
218           .           .           .        200C
              .           .           .           .
              .           .           .           .
223           .           .       DP200............
              .           .           .
              .           .           .
226           .           .           .        200B
              .           .           .           .
              .           .           .           .
231           .           .           .           .         B34
              .           .           .           .           V
              .           .           .           .           V
236           .           .           .           .         J-J
              .           .           .           .           .
              .           .           .           .           .
242           .           .           .           .           .        500C
              .           .           .           .           .           .
              .           .           .           .           .           .
247           .           .           .           .       DP345............
              .           .           .           .           .
              .           .           .           .           .
250           .           .           .           .           .          B5
              .           .           .           .           .           .
              .           .           .           .           .           .
255           .           .           .           .           .           .          B6
              .           .           .           .           .           .           .
              .           .           .           .           .           .           .
260           .           .           .           .           .        DP56............
              .           .           .           .           .           V
              .           .           .           .           .           V
263           .           .           .           .           .         K-K
              .           .           .           .           .           .
              .           .           .           .           .           .
269           .           .           .           .           .           .        500A
              .           .           .           .           .           .           .
              .           .           .           .           .           .           .
274           .           .           .           .       DP500........................
              .           .           .           .           .
              .           .           .           .           .
277           .           .           .           .           .        500B
              .           .           .           .           .           .
              .           .           .           .           .           .
282           .           .           .           .       DP501............
              .           .           .           .           .
              .           .           .           .           .
285           .           .           .           .           .          B7
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                .           .           .           .           .           .
                .           .           .           .           .           .
  290           .           .           .           .           .           .        B8-1
                .           .           .           .           .           .           .
                .           .           .           .           .           .           .
  295           .           .           .           .           .           .           .        B8-2
                .           .           .           .           .           .           .           .
                .           .           .           .           .           .           .           .
  300           .           .           .           .           .           .        DP7.............
                .           .           .           .           .           .           .
                .           .           .           .           .           .           .
  303           .           .           .           .           .           .           .        B8-3
                .           .           .           .           .           .           .           .
                .           .           .           .           .           .           .           .
  308           .           .           .           .           .        DP7A........................
                .           .           .           .           .           .
                .           .           .           .           .           .
  311           .           .           .           .           .           .        400A
                .           .           .           .           .           .           .
                .           .           .           .           .           .           .
  316           .           .           .           .           .       DP401............
                .           .           .           .           .           .
                .           .           .           .           .           .
  319           .           .           .           .           .           .        400B
                .           .           .           .           .           .           .
                .           .           .           .           .           .           .
  324           .           .           .           .           .       DP402............

(***) RUNOFF ALSO COMPUTED AT THIS LOCATION
1*****************************************                                                 ********************************
 *                                       *                                                 *
 *   FLOOD HYDROGRAPH PACKAGE  (HEC-1)   *                                                 *    U.S. ARMY CORPS OF ENGINEER
 *             JUN 09 1992               *                                                 *    HYDROLOGIC ENGINEERING CENT
 *           VERSION 4.0.3E              *                                                 *          609 SECOND STREET
 *                                       *                                                 *       DAVIS, CALIFORNIA 95616
 *  RUN DATE  02/13/98  TIME  15:50:30   *                                                 *           (916) 551-1748
 *                                       *                                                 *
 *****************************************                                                 ********************************




                                BROADMOOR RESORT COMMUNITY (SOUTH) MASTER DRAINAGE PLAN
                                5-YR, 2-HR      DEVELOPED
                                MODIFICATION OF FLO ENGINEERING,INC STUDY/FULL BASIN

   6 IO          OUTPUT CONTROL VARIABLES
                       IPRNT           5  PRINT CONTROL
                       IPLOT           0  PLOT CONTROL
                       QSCAL          0.  HYDROGRAPH PLOT SCALE

     IT          HYDROGRAPH TIME DATA
                        NMIN           1  MINUTES IN COMPUTATION INTERVAL
                       IDATE     22SEP97  STARTING DATE
                       ITIME        1200  STARTING TIME
                          NQ        1500  NUMBER OF HYDROGRAPH ORDINATES
                      NDDATE     23SEP97  ENDING DATE
                      NDTIME        1259  ENDING TIME
                       ICENT          19  CENTURY MARK

                   COMPUTATION INTERVAL    0.02 HOURS
                        TOTAL TIME BASE   24.98 HOURS

          ENGLISH UNITS
               DRAINAGE AREA         SQUARE MILES
               PRECIPITATION DEPTH   INCHES
               LENGTH, ELEVATION     FEET
               FLOW                  CUBIC FEET PER SECOND
               STORAGE VOLUME        ACRE-FEET
               SURFACE AREA          ACRES
               TEMPERATURE           DEGREES FAHRENHEIT
1
                                                        RUNOFF SUMMARY
                                                 FLOW IN CUBIC FEET PER SECOND
                                              TIME IN HOURS,  AREA IN SQUARE MILES

                                           PEAK   TIME OF     AVERAGE FLOW FOR MAXIMUM PERIOD     BASIN     MAXIMUM     TIME OF
          OPERATION        STATION         FLOW    PEAK                                           AREA      STAGE     MAX STAGE
+                                                               6-HOUR      24-HOUR     72-HOUR
```

```
         HYDROGRAPH AT
+                         B12-1      22.    0.70        3.        1.        1.      0.09

         HYDROGRAPH AT
+                         B12-2       7.    0.68        1.        0.        0.      0.03

         2 COMBINED AT
+                           DP1      29.    0.70        4.        1.        1.      0.12

         ROUTED TO
+                           A-A      28.    0.73        4.        1.        1.      0.12
+                                                                                           0.46      0.73

         HYDROGRAPH AT
+                         B12-3       6.    0.73        1.        0.        0.      0.03

         HYDROGRAPH AT
+                         B12-4       9.    0.68        1.        0.        0.      0.04

         HYDROGRAPH AT
+                         B12-7       3.    0.73        0.        0.        0.      0.02

         4 COMBINED AT
+                           DP2      46.    0.72        6.        2.        2.      0.20

         ROUTED TO
+                           B-B      46.    0.75        6.        2.        2.      0.20
+                                                                                           0.81      0.75

         HYDROGRAPH AT
+                         B12-5      23.    0.72        3.        1.        1.      0.08

         HYDROGRAPH AT
+                         B12-8       5.    0.65        1.        0.        0.      0.02

         3 COMBINED AT
+                           DP3      73.    0.73       10.        3.        2.      0.30

         ROUTED TO
+                           C-C      73.    0.75       10.        3.        2.      0.30
+                                                                                           0.94      0.75

         HYDROGRAPH AT
+                         B12-6      18.    0.68        2.        1.        1.      0.06

         HYDROGRAPH AT
+                         B12-9       4.    0.72        1.        0.        0.      0.02

         3 COMBINED AT
+                           DP4      94.    0.75       13.        3.        3.      0.38

         ROUTED TO
+                           D-D      92.    0.78       13.        3.        3.      0.38
+                                                                                           1.19      0.78

         HYDROGRAPH AT
+                         B1210      13.    0.78        2.        1.        0.      0.07

         2 COMBINED AT
+                           DP5     105.    0.78       15.        4.        4.      0.45

         ROUTED TO
+                           E-E     102.    0.83       15.        4.        4.      0.45
+                                                                                           1.53      0.83

         ROUTED TO
+                           DAM      57.    1.32       15.        4.        4.      0.45
+                                                                                        7172.93      1.32

         HYDROGRAPH AT
+                         B1211      11.    0.62        1.        0.        0.      0.04

         2 COMBINED AT
+                           DP6      61.    1.13       17.        4.        4.      0.49

         ROUTED TO
+                           F-F      61.    1.17       17.        4.        4.      0.49
+                                                                                           1.04      1.17

         HYDROGRAPH AT
+                        B10111       7.    0.75        1.        0.        0.      0.04
```

```
            HYDROGRAPH AT
+                          B10112       7.     0.75         1.          0.          0.      0.04

            3 COMBINED AT
+                             DP8      70.     1.13        19.          5.          5.      0.57

            ROUTED TO
+                             G-G      70.     1.17        19.          5.          5.      0.57
+                                                                                                     1.16        1.17

            HYDROGRAPH AT
+                            300A       3.     0.63         1.          0.          0.      0.05

            2 COMBINED AT
+                           DP300      72.     1.17        19.          5.          5.      0.62

            HYDROGRAPH AT
+                              B9      15.     0.73         2.          1.          1.      0.09

            ROUTED TO
+                             H-H      14.     0.78         2.          1.          1.      0.09
+                                                                                                     0.22        0.78

            HYDROGRAPH AT
+                            300B       2.     0.60         0.          0.          0.      0.03

            2 COMBINED AT
+                             DP9      16.     0.80         3.          1.          1.      0.11

            2 COMBINED AT
+                           DP301      84.     1.15        22.          6.          5.      0.73

            ROUTED TO
+                             I-I      84.     1.17        22.          6.          5.      0.73
+                                                                                                     1.25        1.18

            HYDROGRAPH AT
+                            300C       8.     0.80         1.          0.          0.      0.06

            2 COMBINED AT
+                           DP302      90.     1.15        23.          6.          6.      0.79

            HYDROGRAPH AT
+                            100A       4.     0.62         1.          0.          0.      0.05

            HYDROGRAPH AT
+                            100B       2.     0.60         0.          0.          0.      0.02

            2 COMBINED AT
+                           DP101       5.     0.60         1.          0.          0.      0.07

            HYDROGRAPH AT
+                            100C       4.     0.80         1.          0.          0.      0.04

            2 COMBINED AT
+                           DP102       9.     0.67         2.          0.          0.      0.11

            HYDROGRAPH AT
+                            200A       3.     0.82         1.          0.          0.      0.04

            HYDROGRAPH AT
+                            200C       7.     0.78         1.          0.          0.      0.05

            2 COMBINED AT
+                           DP200      10.     0.78         2.          0.          0.      0.09

            HYDROGRAPH AT
+                            200B       2.     0.78         0.          0.          0.      0.02

            HYDROGRAPH AT
+                             B34       5.     0.70         1.          0.          0.      0.02

            ROUTED TO
+                             J-J       5.     0.77         1.          0.          0.      0.02
+                                                                                                     0.08        0.77

            HYDROGRAPH AT
+                            500C       2.     0.73         0.          0.          0.      0.01

            2 COMBINED AT
```

```
+                        DP345      7.   0.77       1.       0.       0.     0.04

          HYDROGRAPH AT
+                           B5      9.   0.72       1.       0.       0.     0.04

          HYDROGRAPH AT
+                           B6      5.   0.72       1.       0.       0.     0.02

          2 COMBINED AT
+                         DP56     13.   0.72       2.       0.       0.     0.06

          ROUTED TO
+                          K-K     12.   0.80       2.       0.       0.     0.06
+                                                                                      0.20      0.80

          HYDROGRAPH AT
+                         500A      5.   0.82       1.       0.       0.     0.04

          3 COMBINED AT
+                        DP500     23.   0.80       4.       1.       1.     0.14

          HYDROGRAPH AT
+                         500B      1.   0.73       0.       0.       0.     0.01

          2 COMBINED AT
+                        DP501     24.   0.78       4.       1.       1.     0.15

          HYDROGRAPH AT
+                           B7      3.   0.68       0.       0.       0.     0.01

          HYDROGRAPH AT
+                         B8-1     12.   0.68       2.       0.       0.     0.06

          HYDROGRAPH AT
+                         B8-2      4.   0.65       0.       0.       0.     0.02

          2 COMBINED AT
+                          DP7     15.   0.68       2.       1.       1.     0.07

          HYDROGRAPH AT
+                         B8-3      4.   0.80       1.       0.       0.     0.02

          3 COMBINED AT
+                         DP7A     22.   0.70       3.       1.       1.     0.11

          HYDROGRAPH AT
+                         400A      2.   0.88       0.       0.       0.     0.02

          2 COMBINED AT
+                        DP401     24.   0.70       4.       1.       1.     0.13

          HYDROGRAPH AT
+                         400B      1.   0.88       0.       0.       0.     0.01

          2 COMBINED AT
+                        DP402     24.   0.72       4.       1.       1.     0.14


 *** NORMAL END OF HEC-1 ***
```

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1*****************************************                                    ********************************
 *                                       *                                    *
 *   FLOOD HYDROGRAPH PACKAGE  (HEC-1)   *                                    *   U.S. ARMY CORPS OF ENGINEER
 *             JUN 09 1992               *                                    *   HYDROLOGIC ENGINEERING CENT
 *           VERSION 4.0.3E              *                                    *         609 SECOND STREET
 *                                       *                                    *      DAVIS, CALIFORNIA 95616
 *  RUN DATE  02/13/98  TIME  15:47:58   *                                    *          (916) 551-1748
 *                                       *                                    *
 *****************************************                                    ********************************




                         X     X  XXXXXXX   XXXXX        X
                         X     X  X        X     X      XX
                         X     X  X        X             X
                         XXXXXXX  XXXX     X     XXXXX   X
                         X     X  X        X             X
                         X     X  X        X     X       X
                         X     X  XXXXXXX   XXXXX       XXX




        THIS PROGRAM REPLACES ALL PREVIOUS VERSIONS OF HEC-1 KNOWN AS HEC1 (JAN 73), HEC1GS, HEC1DB, AND HEC1KW.

        THE DEFINITIONS OF VARIABLES -RTIMP- AND -RTIOR- HAVE CHANGED FROM THOSE USED WITH THE 1973-STYLE INPUT STRUCTURE
        THE DEFINITION OF -AMSKK- ON RM-CARD WAS CHANGED WITH REVISIONS DATED 28 SEP 81. THIS IS THE FORTRAN77 VERSION
        NEW OPTIONS: DAMBREAK OUTFLOW SUBMERGENCE , SINGLE EVENT DAMAGE CALCULATION, DSS:WRITE STAGE FREQUENCY,
        DSS:READ TIME SERIES AT DESIRED CALCULATION INTERVAL   LOSS RATE:GREEN AND AMPT INFILTRATION
        KINEMATIC WAVE: NEW FINITE DIFFERENCE ALGORITHM

1                                         HEC-1 INPUT                                                     PAGE  1

        LINE          ID.......1.......2.......3.......4.......5.......6.......7.......8.......9......10

          1           ID        BROADMOOR RESORT COMMUNITY (SOUTH) MASTER DRAINAGE PLAN
          2           ID        100-YR,2-HR     DEVELOPED       with Fishers Canyon Debris Structure
          3           ID        MODIFICATION OF FLO ENGINEERING,INC STUDY/FULL BASIN
                      *DIAGRAM
          4           IT       1 22SEP97    1200    1500
          5           IN       5
          6           IO       5       0

          7           KK   B12-1
          8           KM        RUNOFF FROM SDA 12-1
          9           BA    .089
         10           PB     3.1
         11           PI     .01     .03     .04     .07     .12     .22     .12     .07     .05     .04
         12           PI     .03     .03     .03     .02     .02     .01     .01     .01     .01     .01
         13           PI     .01     .01     .01     .01
         14           LS       0      76       6
         15           UD    .126

         16           KK   B12-2
         17           KM        RUNOFF FROM SDA 12-2
         18           BA    .028
         19           LS       0      76       6
         20           UD    .113

         21           KK     DP1
         22           KM        COMBINE FLOWS FROM SDAs 12-1, 12-2
         23           HC       2

         24           KK     A-A
         25           KM        ROUTE FLOWS FROM CP1 TO CP2
         26           RS       1    STOR       0
         27           RC    0.12     .08    0.12     630    0.24
         28           RX       0       5      10      20      28      38      43      48
         29           RY      15    12.5      10       0       0      10    12.5      15

         30           KK   B12-3
         31           KM        RUNOFF FROM SDA 12-3
         32           BA    .027
         33           LS       0      76       6
         34           UD    .145

         35           KK   B12-4
         36           KM        RUNOFF FROM SDA 12-4
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       37          BA    .038
       38          LS       0      75       6
       39          UD    .110

       40          KK   B12-7
       41          KM        RUNOFF FROM SDA 12-7
       42          BA    .016
       43          LS       0      75       5
       44          UD    .134
1                                           HEC-1 INPUT                                             PAGE  2

     LINE          ID.......1.......2.......3.......4.......5.......6.......7.......8.......9......10


       45          KK     DP2
       46          KM        COMBINE CP1 & SDAs 12-3, 12-4, 12-7
       47          HC       4

       48          KK     B-B
       49          KM        ROUTE FLOWS FROM CP2 TO CP3
       50          RS       1    STOR       0
       51          RC    0.12     .08    0.12     790    0.19
       52          RX       0       5      10      20      28      38      43      48
       53          RY      15    12.5      10       0       0      10    12.5      15

       54          KK   B12-5
       55          KM        RUNOFF FROM SDA 12-5
       56          BA    .081
       57          LS       0      76      10
       58          UD    .154

       59          KK   B12-8
       60          KM        RUNOFF FROM SDA 12-8
       61          BA    .023
       62          LS       0      75       5
       63          UD    .077

       64          KK     DP3
       65          KM        COMBINE FLOWS FROM CP2 & SDAs 12-5, 12-8
       66          HC       3

       67          KK     C-C
       68          KM        ROUTE FLOW FROM CP3 TO CP4
       69          RS       1    STOR       0
       70          RC    0.12     .08    0.12     650    0.26
       71          RX       0       5      10      20      28      38      43      48
       72          RY      15    12.5      10       0       0      10    12.5      15

       73          KK   B12-6
       74          KM        RUNOFF FROM SDA 12-6
       75          BA    .061
       76          LS       0      76      10
       77          UD    .129

       78          KK   B12-9
       79          KM        RUNOFF FROM SDA 12-9
       80          BA    .021
       81          LS       0      75       4
       82          UD    .112

       83          KK     DP4
       84          KM        COMBINE FLOWS FROM CP3 & SDAs 12-6, 12-9
       85          HC       3
1                                           HEC-1 INPUT                                             PAGE  3

     LINE          ID.......1.......2.......3.......4.......5.......6.......7.......8.......9......10


       86          KK     D-D
       87          KM        ROUTE FLOWS FROM CP4 TO CP5
       88          RS       1    STOR       0
       89          RC    0.12     .08    0.12    1420    0.19
       90          RX       0       5      10      20      28      38      43      48
       91          RY      15    12.5      10       0       0      10    12.5      15

       92          KK   B1210
       93          KM        RUNOFF FROM SDA 12-10
       94          BA    .069
       95          LS       0      75       5
       96          UD    .170
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  97          KK     DP5
  98          KM       COMBINE FLOWS FROM CP4 & SDA 1210
  99          HC       2

 100          KK     E-E
 101          KM       ROUTE FLOW FROM CP5 TO CP6
 102          RS       1    STOR       0
 103          RC    0.12     .08    0.12    1420    0.11
 104          RX       0       5      10      20      28      38      43      48
 105          RY      15    12.5      10       0       0      10    12.5      15

 106          KK     DAM
 107          KM       ROUTE FLOW THROUGH FISHERS CANYON DEBRIS CONTROL STRUCTURE
 108          RS       1    ELEV    7155
 109          SV       0     0.3    0.75    1.35    2.55     3.6     3.8     6.1     8.5    11.0
 110          SV    13.5    16.1    18.8
 111          SE    7155    7160    7165    7170    7175    7178    7180    7182    7184    7186
 112          SE    7188    7190    7192
 113          SQ       0      19      39      51      61      67      70     158     197     227
 114          SQ    1853    4801    8610

 115          KK   B1211
 116          KM       RUNOFF FROM SDA 12-11
 117          BA    .041
 118          LS       0      74      10
 119          UD    .073

 120          KK     DP6
 121          KM       COMBINE DP5 & 1211
 122          HC       2

 123          KK     F-F
 124          KM       ROUTE FLOW FROM 12-11 TO 1011-1
 125          RS       1    STOR       0
 126          RC    0.12     .08    0.12    1200     .13
 127          RX       0       5      10      20      28      38      43      48
 128          RY      15    12.5      10       0       0      10    12.5      15
1                                             HEC-1 INPUT                                          PAGE  4

LINE          ID.......1.......2.......3.......4.......5.......6.......7.......8.......9......10


 129          KK  B10111
 130          KM       RUNOFF FROM SDA 1011-1
 131          BA    .035
 132          LS       0      74       7
 133          UD    .160

 134          KK  B10112
 135          KM       RUNOFF FROM SDA 1011-2
 136          BA    .037
 137          LS       0      74       7
 138          UD    .160

 139          KK     DP8
 140          KM       COMBINE FLOW FROM SDA 1012 & CP6A
 141          HC       3

 142          KK     G-G
 143          KM       ROUTE FLOW FROM DP8 TO DP300
 144          RS       1    STOR       0
 145          RC    0.12     .08    0.12    1200     .12
 146          RX       0       5      10      20      28      38      43      48
 147          RY      15    12.5      10       0       0      10    12.5      15

 148          KK    300A
 149          KM       RUNOFF FROM 300A
 150          BA    .049
 151          LS       0      65       4
 152          UD    .162

 153          KK   DP300
 154          KM       COMBINE FLOWS FROM CP8 & SDA 300A
 155          HC       2

 156          KK      B9
 157          KM       RUNOFF FROM SDA 9
 158          BA    .085
 159          LS       0      74       4
 160          UD    .125
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            161           KK     H-H
            162           KM        ROUTE FLOW FROM B9 THRU SDA 300B
            163           RS       1    STOR       0
            164           RC    0.12     .08    0.12    1200     .25
            165           RX       0       5      10      20      28      38      43      48
            166           RY      15    12.5      10       0       0      10    12.5      15

            167           KK    300B
            168           KM        RUNOFF FROM 300B
            169           BA    .026
            170           LS       0      68       4
            171           UD    .126
1                                                       HEC-1 INPUT                                                     PAGE  5

           LINE           ID.......1.......2.......3.......4.......5.......6.......7.......8.......9......10


            172           KK     DP9
            173           KM        COMBINE SDA B9 & 300B
            174           HC       2

            175           KK   DP301
            176           KM        COMBINE FLOWS FROM CP300 & SDA 300B
            177           HC       2

            178           KK     I-I
            179           KM        ROUTE FLOW FROM B9 THRU SDA 300B
            180           RS       1    STOR       0
            181           RC    0.12     .08    0.12    1800     .17
            182           RX       0       4     5.5     6.5    14.5    15.5      17      21
            183           RY       7       5       2       0       0       2       5       7

            184           KK    300C
            185           KM        RUNOFF FROM SDA 300C
            186           BA     .06
            187           LS       0      72       4
            188           UD    .150

            189           KK   DP302
            190           KM        COMBINE FLOWS FROM CP301 & 300C
            191           HC       2

            192           KK    100A
            193           KM        RUNOFF FROM SDA 100A
            194           BA    .048
            195           LS       0      66       4
            196           UD    .138

            197           KK    100B
            198           KM        RUNOFF FROM SDA 100B
            199           BA    .022
            200           LS       0      66       4
            201           UD    .132

            202           KK   DP101
            203           KM        COMBINE FLOWS FROM CP100 & SDA 100B
            204           HC       2

            205           KK    100C
            206           KM        RUNOFF FROM SDA 100C
            207           BA    .035
            208           LS       0      72       4
            209           UD    .150

            210           KK   DP102
            211           KM        COMBINE FLOWS FROM CP101 & SDA 100C
            212           HC       2
1                                                       HEC-1 INPUT                                                     PAGE  6

           LINE           ID.......1.......2.......3.......4.......5.......6.......7.......8.......9......10


            213           KK    200A
            214           KM        RUNOFF FROM 200A
            215           BA    .035
            216           LS       0      70       4
            217           UD    .144

            218           KK    200C
            219           KM        RUNOFF FROM 200C
            220           BA    .051
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      221           LS       0       72       4
      222           UD     .144

      223           KK    DP200
      224           KM         COMBINE FLOWS FROM SDAs 200A & 200C
      225           HC       2

      226           KK     200B
      227           KM         RUNOFF FROM 200B
      228           BA     .017
      229           LS       0       72       4
      230           UD     .144

      231           KK      B34
      232           KM         RUNOFF FROM SDA       34
      233           BA     .023
      234           LS       0       74       7
      235           UD     .125

      236           KK      J-J
      237           KM         ROUTE FLOW FROM B3 THRU 500C
      238           RS       1    STOR        0
      239           RC     0.12     .08    0.12    1500     .21
      240           RX       0       5      10      20      28      38      43      48
      241           RY      15    12.5      10       0       0      10    12.5      15

      242           KK     500C
      243           KM          RUNOFF FROM 500C
      244           BA     .015
      245           LS       0       72       4
      246           UD     .108

      247           KK    DP345
      248           KM         COMBINE SDAs 34 & 500C
      249           HC       2

      250           KK       B5
      251           KM         RUNOFF FROM SDA 5
      252           BA     .042
      253           LS       0       74       7
      254           UD     .131
1                                              HEC-1 INPUT                                                   PAGE  7

    LINE            ID.......1.......2.......3.......4.......5.......6.......7.......8.......9......10


      255           KK       B6
      256           KM         RUNOFF FROM SDA 6
      257           BA     .022
      258           LS       0       74       7
      259           UD     .131

      260           KK     DP56
      261           KM         COMBINE FLOWS FROM SDAs 5&6
      262           HC       2

      263           KK      K-K
      264           KM         ROUTE FLOW FROM DP 56 THRU 500A
      265           RS       1    STOR        0
      266           RC     0.12     .08    0.12    2100     .22
      267           RX       0       5      10      20      28      38      43      48
      268           RY      15    12.5      10       0       0      10    12.5      15

      269           KK     500A
      270           KM         RUNOFF FROM SDA 500A
      271           BA     .036
      272           LS       0       72       4
      273           UD     .162

      274           KK    DP500
      275           KM         COMBINE FLOWS FROM CP56&500A
      276           HC       3

      277           KK     500B
      278           KM         RUNOFF FROM SDA 500B
      279           BA     .009
      280           LS       0       72       4
      281           UD     .108

      282           KK    DP501
      283           KM         COMBINE FLOWS FROM CP5A&500B
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           284          HC        2

           285          KK       B7
           286          KM          RUNOFF FROM SDA 7
           287          BA     .014
           288          LS        0      74        7
           289          UD     .107

           290          KK     B8-1
           291          KM          RUNOFF FROM SDA 8-1
           292          BA     .056
           293          LS        0      74        7
           294          UD     .113
1                                                      HEC-1 INPUT                                                     PAGE  8

          LINE          ID.......1.......2.......3.......4.......5.......6.......7.......8.......9......10


           295          KK     B8-2
           296          KM          RUNOFF FROM SDA 8-2
           297          BA     .016
           298          LS        0      74        7
           299          UD     .086

           300          KK      DP7
           301          KM          COMBINE FLOWS FROM SDAs 8-1, 8-2
           302          HC        2

           303          KK     B8-3
           304          KM          RUNOFF FROM SDA 8-3
           305          BA     .021
           306          LS        0      74        7
           307          UD     .202

           308          KK     DP7A
           309          KM          COMBINE FLOW FROM CP7 & SDA 8-3 &B7
           310          HC        3

           311          KK     400A
           312          KM          RUNOFF FROM SDA     400A
           313          BA      .02
           314          LS        0      72        4
           315          UD     .210

           316          KK    DP401
           317          KM          COMBINE FLOWS FROM DP7A & SDA 400A
           318          HC        2

           319          KK     400B
           320          KM          RUNOFF FROM SDA     400B
           321          BA      .01
           322          LS        0      72        4
           323          UD     .210

           324          KK    DP402
           325          KM          COMBINE FLOWS FROM DP402& SDA 400B
           326          HC        2
           327          ZZ
1
                SCHEMATIC DIAGRAM OF STREAM NETWORK
 INPUT
  LINE      (V) ROUTING         (--->) DIVERSION OR PUMP FLOW

   NO.      (.) CONNECTOR       (<---) RETURN OF DIVERTED OR PUMPED FLOW

     7       B12-1
                 .
                 .
    16           .       B12-2
                 .            .
                 .            .
    21         DP1............
                 V
                 V
    24         A-A
                 .
                 .
    30           .       B12-3
                 .            .
                 .            .
    35           .            .      B12-4
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             .           .           .
 40          .           .           .       B12-7
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 45        DP2....................................
             V
             V
 48        B-B
             .
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 54          .       B12-5
             .           .
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 59          .           .       B12-8
             .           .           .
             .           .           .
 64        DP3........................
             V
             V
 67        C-C
             .
             .
 73          .       B12-6
             .           .
             .           .
 78          .           .       B12-9
             .           .           .
             .           .           .
 83        DP4........................
             V
             V
 86        D-D
             .
             .
 92          .       B1210
             .           .
             .           .
 97        DP5............
             V
             V
100        E-E
             V
             V
106        DAM
             .
             .
115          .       B1211
             .           .
             .           .
120        DP6............
             V
             V
123        F-F
             .
             .
129          .      B10111
             .           .
             .           .
134          .           .      B10112
             .           .           .
             .           .           .
139        DP8........................
             V
             V
142        G-G
             .
             .
148          .        300A
             .           .
             .           .
153      DP300............
             .
             .
156          .          B9
             .           V
             .           V
161          .         H-H
             .           .
             .           .
167          .           .        300B
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             .           .           .
             .           .           .
172          .         DP9............
             .           .
             .           .
175      DP301............
             V
             V
178        I-I
             .
             .
184          .        300C
             .           .
             .           .
189      DP302............
             .
             .
192          .        100A
             .           .
             .           .
197          .           .        100B
             .           .           .
             .           .           .
202          .       DP101............
             .           .
             .           .
205          .           .        100C
             .           .           .
             .           .           .
210          .       DP102............
             .           .
             .           .
213          .           .        200A
             .           .           .
             .           .           .
218          .           .           .        200C
             .           .           .           .
             .           .           .           .
223          .           .       DP200............
             .           .           .
             .           .           .
226          .           .           .        200B
             .           .           .           .
             .           .           .           .
231          .           .           .           .         B34
             .           .           .           .           V
             .           .           .           .           V
236          .           .           .           .         J-J
             .           .           .           .           .
             .           .           .           .           .
242          .           .           .           .           .        500C
             .           .           .           .           .           .
             .           .           .           .           .           .
247          .           .           .           .       DP345............
             .           .           .           .           .
             .           .           .           .           .
250          .           .           .           .           .          B5
             .           .           .           .           .           .
             .           .           .           .           .           .
255          .           .           .           .           .           .          B6
             .           .           .           .           .           .           .
             .           .           .           .           .           .           .
260          .           .           .           .           .        DP56............
             .           .           .           .           .           V
             .           .           .           .           .           V
263          .           .           .           .           .         K-K
             .           .           .           .           .           .
             .           .           .           .           .           .
269          .           .           .           .           .           .        500A
             .           .           .           .           .           .           .
             .           .           .           .           .           .           .
274          .           .           .           .       DP500........................
             .           .           .           .           .
             .           .           .           .           .
277          .           .           .           .           .        500B
             .           .           .           .           .           .
             .           .           .           .           .           .
282          .           .           .           .       DP501............
             .           .           .           .           .
             .           .           .           .           .
285          .           .           .           .           .          B7
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  290           .           .           .           .           .           .        B8-1
                .           .           .           .           .           .           .
                .           .           .           .           .           .           .
  295           .           .           .           .           .           .           .        B8-2
                .           .           .           .           .           .           .           .
                .           .           .           .           .           .           .           .
  300           .           .           .           .           .           .         DP7............
                .           .           .           .           .           .           .
                .           .           .           .           .           .           .
  303           .           .           .           .           .           .           .        B8-3
                .           .           .           .           .           .           .           .
                .           .           .           .           .           .           .           .
  308           .           .           .           .           .        DP7A........................
                .           .           .           .           .           .
                .           .           .           .           .           .
  311           .           .           .           .           .           .        400A
                .           .           .           .           .           .           .
                .           .           .           .           .           .           .
  316           .           .           .           .           .       DP401............
                .           .           .           .           .           .
                .           .           .           .           .           .
  319           .           .           .           .           .           .        400B
                .           .           .           .           .           .           .
                .           .           .           .           .           .           .
  324           .           .           .           .           .       DP402............
(***) RUNOFF ALSO COMPUTED AT THIS LOCATION
1*****************************************                                                       ********************************
*                                        *                                                       *
*   FLOOD HYDROGRAPH PACKAGE  (HEC-1)    *                                                       *   U.S. ARMY CORPS OF ENGINEER
*              JUN 09 1992               *                                                       *   HYDROLOGIC ENGINEERING CENT
*            VERSION 4.0.3E              *                                                       *         609 SECOND STREET
*                                        *                                                       *      DAVIS, CALIFORNIA 95616
*  RUN DATE  02/13/98  TIME  15:47:58    *                                                       *          (916) 551-1748
*                                        *                                                       *
******************************************                                                       ********************************




                                   BROADMOOR RESORT COMMUNITY (SOUTH) MASTER DRAINAGE PLAN
                                   100-YR,2-HR     DEVELOPED       with Fishers Canyon Debris Structure
                                   MODIFICATION OF FLO ENGINEERING,INC STUDY/FULL BASIN

   6 IO          OUTPUT CONTROL VARIABLES
                       IPRNT          5  PRINT CONTROL
                       IPLOT          0  PLOT CONTROL
                       QSCAL         0.  HYDROGRAPH PLOT SCALE

     IT          HYDROGRAPH TIME DATA
                        NMIN          1  MINUTES IN COMPUTATION INTERVAL
                       IDATE    22SEP97  STARTING DATE
                       ITIME       1200  STARTING TIME
                          NQ       1500  NUMBER OF HYDROGRAPH ORDINATES
                      NDDATE    23SEP97  ENDING DATE
                      NDTIME       1259  ENDING TIME
                       ICENT         19  CENTURY MARK

                   COMPUTATION INTERVAL    0.02 HOURS
                        TOTAL TIME BASE   24.98 HOURS

          ENGLISH UNITS
               DRAINAGE AREA           SQUARE MILES
               PRECIPITATION DEPTH     INCHES
               LENGTH, ELEVATION       FEET
               FLOW                    CUBIC FEET PER SECOND
               STORAGE VOLUME          ACRE-FEET
               SURFACE AREA            ACRES
               TEMPERATURE             DEGREES FAHRENHEIT
1
                                                                   RUNOFF SUMMARY
                                                              FLOW IN CUBIC FEET PER SECOND
                                                           TIME IN HOURS,  AREA IN SQUARE MILES

                                              PEAK    TIME OF       AVERAGE FLOW FOR MAXIMUM PERIOD          BASIN      MAXIMUM      TIME OF
              OPERATION        STATION        FLOW     PEAK                                                   AREA       STAGE      MAX STAGE
+                                                                    6-HOUR      24-HOUR       72-HOUR
```

```
          HYDROGRAPH AT
+                           B12-1      112.    0.65        12.        3.        3.     0.09
          HYDROGRAPH AT
+                           B12-2       37.    0.63         4.        1.        1.     0.03
          2 COMBINED AT
+                             DP1      148.    0.65        15.        4.        4.     0.12
          ROUTED TO
+                             A-A      148.    0.67        15.        4.        4.     0.12
+                                                                                              1.51      0.67
          HYDROGRAPH AT
+                           B12-3       32.    0.68         3.        1.        1.     0.03
          HYDROGRAPH AT
+                           B12-4       47.    0.63         5.        1.        1.     0.04
          HYDROGRAPH AT
+                           B12-7       18.    0.67         2.        0.        0.     0.02
          4 COMBINED AT
+                             DP2      244.    0.67        25.        6.        6.     0.20
          ROUTED TO
+                             B-B      242.    0.68        25.        6.        6.     0.20
+                                                                                              2.15      0.68
          HYDROGRAPH AT
+                           B12-5      102.    0.68        11.        3.        3.     0.08
          HYDROGRAPH AT
+                           B12-8       31.    0.60         3.        1.        1.     0.02
          3 COMBINED AT
+                             DP3      369.    0.67        39.       10.        9.     0.30
          ROUTED TO
+                             C-C      369.    0.68        39.       10.        9.     0.30
+                                                                                              2.52      0.68
          HYDROGRAPH AT
+                           B12-6       82.    0.65         8.        2.        2.     0.06
          HYDROGRAPH AT
+                           B12-9       25.    0.65         3.        1.        1.     0.02
          3 COMBINED AT
+                             DP4      472.    0.68        50.       13.       12.     0.38
          ROUTED TO
+                             D-D      466.    0.70        50.       13.       12.     0.38
+                                                                                              3.16      0.70
          HYDROGRAPH AT
+                           B1210       72.    0.72         8.        2.        2.     0.07
          2 COMBINED AT
+                             DP5      537.    0.70        59.       15.       14.     0.45
          ROUTED TO
+                             E-E      527.    0.73        59.       15.       14.     0.45
+                                                                                              3.93      0.73
          ROUTED TO
+                             DAM      222.    1.18        59.       15.       14.     0.45
+                                                                                           7185.67      1.18
          HYDROGRAPH AT
+                           B1211       57.    0.58         5.        1.        1.     0.04
          2 COMBINED AT
+                             DP6      240.    1.12        64.       16.       15.     0.49
          ROUTED TO
+                             F-F      239.    1.13        64.       16.       15.     0.49
+                                                                                              2.41      1.13
          HYDROGRAPH AT
+                          B10111       37.    0.70         4.        1.        1.     0.04
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          HYDROGRAPH AT
+                       B10112      39.    0.70          4.        1.        1.     0.04
          3 COMBINED AT
+                          DP8     274.    1.10         73.       18.       17.     0.57
          ROUTED TO
+                          G-G     274.    1.10         73.       18.       17.     0.57
+                                                                                            2.64      1.10
          HYDROGRAPH AT
+                         300A      25.    0.75          3.        1.        1.     0.05
          2 COMBINED AT
+                        DP300     293.    0.95         76.       19.       18.     0.62
          HYDROGRAPH AT
+                           B9      91.    0.67         10.        2.        2.     0.09
          ROUTED TO
+                          H-H      89.    0.68         10.        2.        2.     0.09
+                                                                                            1.07      0.68
          HYDROGRAPH AT
+                         300B      18.    0.68          2.        1.        1.     0.03
          2 COMBINED AT
+                          DP9     107.    0.68         12.        3.        3.     0.11
          2 COMBINED AT
+                        DP301     362.    0.87         88.       22.       21.     0.73
          ROUTED TO
+                          I-I     361.    0.90         88.       22.       21.     0.73
+                                                                                            2.96      0.90
          HYDROGRAPH AT
+                         300C      53.    0.70          6.        2.        1.     0.06
          2 COMBINED AT
+                        DP302     399.    0.88         94.       23.       23.     0.79
          HYDROGRAPH AT
+                         100A      28.    0.72          4.        1.        1.     0.05
          HYDROGRAPH AT
+                         100B      13.    0.70          2.        0.        0.     0.02
          2 COMBINED AT
+                        DP101      41.    0.72          5.        1.        1.     0.07
          HYDROGRAPH AT
+                         100C      31.    0.70          4.        1.        1.     0.04
          2 COMBINED AT
+                        DP102      71.    0.70          9.        2.        2.     0.11
          HYDROGRAPH AT
+                         200A      27.    0.70          3.        1.        1.     0.04
          HYDROGRAPH AT
+                         200C      45.    0.70          5.        1.        1.     0.05
          2 COMBINED AT
+                        DP200      73.    0.70          9.        2.        2.     0.09
          HYDROGRAPH AT
+                         200B      15.    0.70          2.        0.        0.     0.02
          HYDROGRAPH AT
+                          B34      26.    0.65          3.        1.        1.     0.02
          ROUTED TO
+                          J-J      24.    0.73          3.        1.        1.     0.02
+                                                                                            0.41      0.73
          HYDROGRAPH AT
+                         500C      15.    0.65          2.        0.        0.     0.01
          2 COMBINED AT
```

```
+                      DP345        37.    0.70         4.         1.         1.      0.04

          HYDROGRAPH AT
+                         B5        47.    0.67         5.         1.         1.      0.04

          HYDROGRAPH AT
+                         B6        25.    0.67         3.         1.         1.      0.02

          2 COMBINED AT
+                       DP56        72.    0.67         8.         2.         2.      0.06

          ROUTED TO
+                        K-K        66.    0.73         8.         2.         2.      0.06
+                                                                                                  0.94       0.73

          HYDROGRAPH AT
+                       500A        31.    0.72         4.         1.         1.      0.04

          3 COMBINED AT
+                      DP500       133.    0.72        16.         4.         4.      0.14

          HYDROGRAPH AT
+                       500B         9.    0.65         1.         0.         0.      0.01

          2 COMBINED AT
+                      DP501       141.    0.72        17.         4.         4.      0.15

          HYDROGRAPH AT
+                         B7        17.    0.63         2.         0.         0.      0.01

          HYDROGRAPH AT
+                       B8-1        66.    0.65         7.         2.         2.      0.06

          HYDROGRAPH AT
+                       B8-2        20.    0.60         2.         0.         0.      0.02

          2 COMBINED AT
+                        DP7        86.    0.63         9.         2.         2.      0.07

          HYDROGRAPH AT
+                       B8-3        20.    0.77         3.         1.         1.      0.02

          3 COMBINED AT
+                       DP7A       117.    0.65        13.         3.         3.      0.11

          HYDROGRAPH AT
+                       400A        16.    0.78         2.         1.         0.      0.02

          2 COMBINED AT
+                      DP401       128.    0.65        15.         4.         4.      0.13

          HYDROGRAPH AT
+                       400B         8.    0.78         1.         0.         0.      0.01

          2 COMBINED AT
+                      DP402       134.    0.67        16.         4.         4.      0.14


 *** NORMAL END OF HEC-1 ***
```

Subject BROADMOOR - HEC-1 FLOW SCHEMATIC

Project No. 2C589

By

Checked By SWR

Task No. 600

File No.

Date 9/25/97

Date 10/08/97

Sheet 1/2

OBJECTIVE:

DEVELOP FLOW SCHEMATIC FOR FISCHERS CANYON DEVELOPMENTS HEC-1 MODELING

GIVEN:

SITE TOPO

SOLUTION:

SEE ATTACHED

Subject

By

Checked By

Date

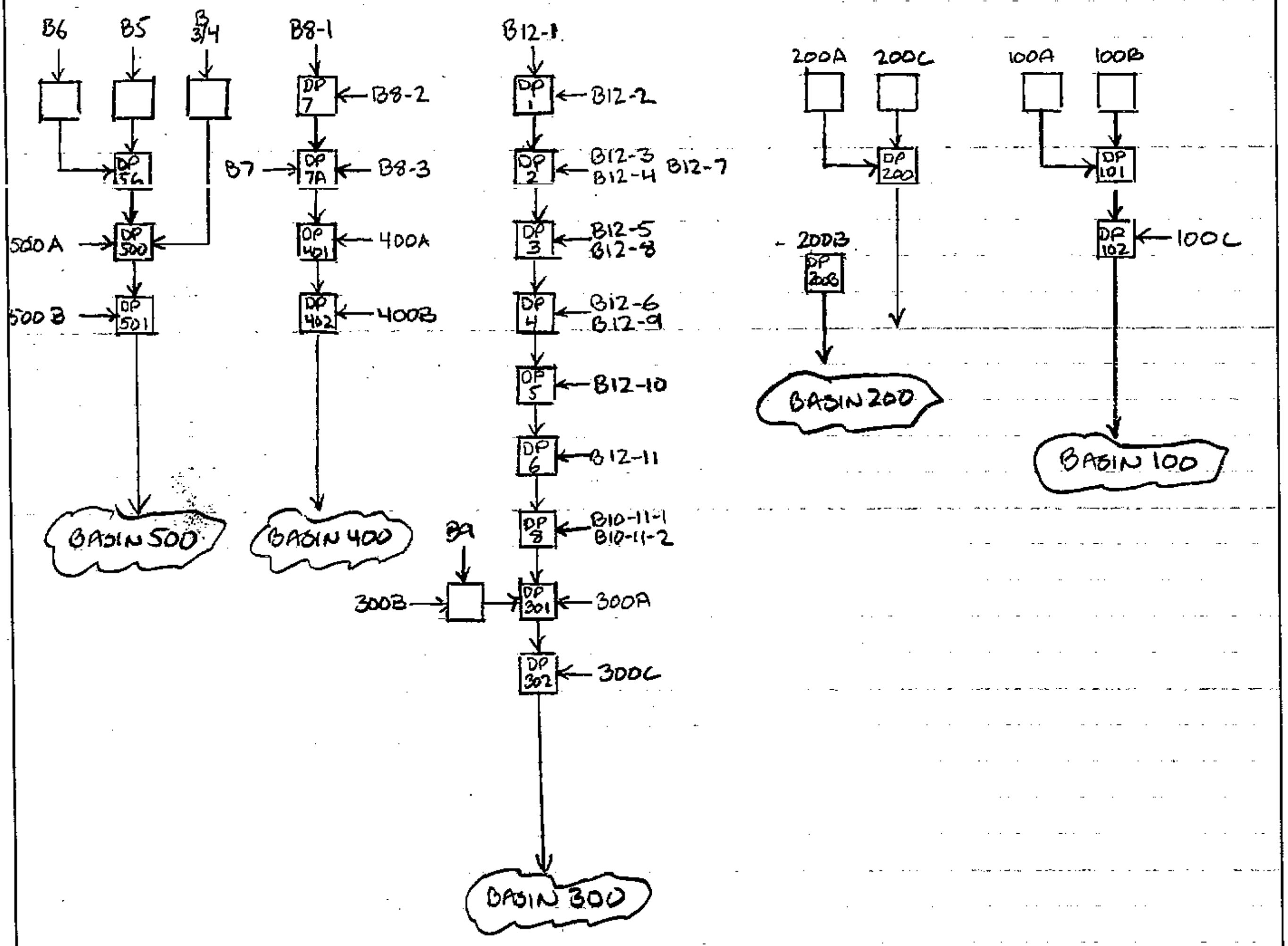
Date

Project No.

Task No.

File No.

Sheet 2 of 2



Subject BROADMOOR - SUBBASIN 12 PARAMETERS

Project No. 24389

By SDD

Checked By SWR

Task No. 600

File No.

Date 9/24/97

Date 10/08/97

Sheet 1 of 5

OBJECTIVE:

DEVELOP HYDROLOGIC PARAMETERS FOR SUB-BASINS 12-1 TO 12-11

GIVEN:

SITE TOPOS (1:7560 & 1:2400)

SOLUTION:

REFER TO ATTACHED SHEETS

Woodward-Clyde

Project: Broadmoor-Fischers Canyon
Project #: 24389

Objective: Develop time of travel/concentration for individual basins (12-1 to 12-11)

Formula: Kirpich's $tc = 0.0078L^{0.77}S^{-0.385}$

Analysis:

Sub-Basin (ID)	Length (feet)	Elev1 (ft)	Elev2 (ft)	Slope (ft/ft)	tc (min)	tc (hr)	%	tc+% (hr)	Calibrated lag time
3	1420	7140	8000	0.606	2.530	0.04	0.77	0.075	0.125
5	2100	6990	8230	0.590	3.454	0.06	0.41	0.081	0.131
6	2100	6990	8250	0.600	3.433	0.06	0.41	0.081	0.131
7	300	6855	6920	0.217	1.136	0.02	2.00	0.057	0.107
8-1	2950	7060	8580	0.515	4.729	0.08	-0.20	0.063	0.133
8-2	1550	7060	8000	0.606	2.706	0.05	-0.20	0.036	0.086
8-3	4650	6450	7060	0.131	11.367	0.19	-0.20	0.152	0.202
9	400	6810	8120	3.275	0.498	0.01	2.00	0.025	0.125
1011-1	2550	6930	7800	0.341	4.954	0.08	3.80	0.396	0.160
1011-2	1500	6930	7150	0.147	4.557	0.08	3.80	0.365	0.160
1011-3	-	-	-	-	-	-	-	-	
12-1	1350	8350	9350	0.741	2.252	0.04	1.03	0.076	0.126
12-2	850	7950	8350	0.471	1.878	0.03	1.03	0.063	0.113
12-3	1500	7850	8620	0.513	2.813	0.05	1.03	0.095	0.145
12-4	900	7800	8350	0.611	1.775	0.03	1.03	0.060	0.110
12-5	1850	7650	8800	0.622	3.071	0.05	1.03	0.104	0.154
12-6	1200	7520	8150	0.525	2.349	0.04	1.03	0.079	0.129
12-7	1350	7890	8650	0.563	2.503	0.04	1.03	0.084	0.134
12-8	550	7000	8000	1.818	0.798	0.01	1.03	0.027	0.077
12-9	900	7550	8050	0.556	1.841	0.03	1.03	0.062	0.112
12-10	1350	7214	7520	0.227	3.553	0.06	1.03	0.120	0.170
12-11	200	7140	7214	0.370	0.676	0.01	1.03	0.023	0.073

Subject
Project No.
By
Checked By
Task No.
File No.
Date
Date
Sheet 3 of 5

OFF-SITE DRAINAGE AREAS

8-1	0.056	mi^2
8-2	0.016	mi^2
8-3	0.021	mi^2
10U-1	0.035	mi^2
10U-2	0.037	mi^2
10U-3		mi^2
12-1	0.088	mi^2
12-2	0.028	mi^2
12-3	0.027	mi^2
12-4	0.038	mi^2
12-5	0.08	mi^2
12-6	0.06	mi^2
12-7	0.016	mi^2
12-8	0.023	mi^2
12-9	0.021	mi^2
12-10	0.068	mi^2
12-11	0.04	mi^2
5	0.042	mi^2
6	0.022	mi^2

Subject

Project No.

By

Checked By

Task No.

File No.

Date

Date

Sheet 4 of 5

Basin	Channel Length	Elev1	Elev2	
12-1	1550	8350	9350	
12-2	850	7950	8350	
12-3	1500	7850	8620	
12-4	900	7800	8350	
12-5	1850	7650	8800	
12-6	1200	7520	8150	
12-7	1350	7890	8650	
12-8	550	7000	8000	
12-9	900	7550	8050	
12-10	1350	7214	7520	
12-11	200	7140	7214	
5	2100	6990	8250	
6	2100	6990	8250	
7	300	6855	6920	
8-1	2950	7060	8880	
8-2	1550	7060	8000	
8-3	4650	6450	7060	
9	4000	6810	8120	
1011-1	2550	6930	7800	
1011-2	1500	6930	7150	
1011-3 (?)	—	—	—	(TBD)

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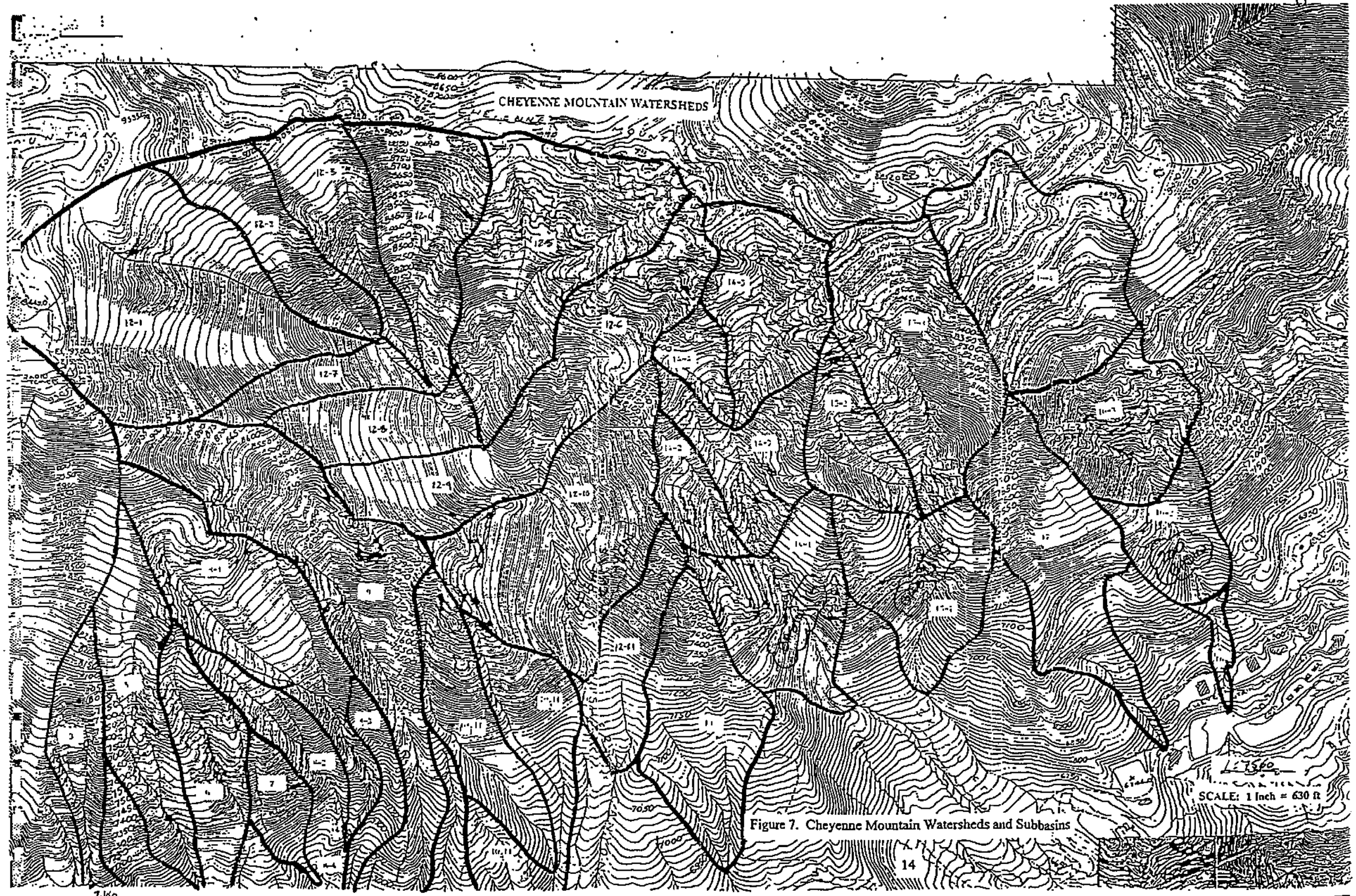


Figure 7. Cheyenne Mountain Watersheds and Subbasins

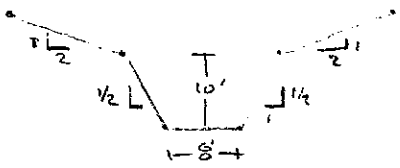
Subject Broadmoor – Channel Characteristics
Project No. 24389
By
Checked By SWR
Task No. 600
File No.
Date 9/25/97
Date 10/08/97
Sheet 1 of 1

OBJECTIVE:

Estimate channel characteristics for routing w/in Fickers Canyon

GIVEN:

Site Topo (1=7560)
Channel Dimensions:



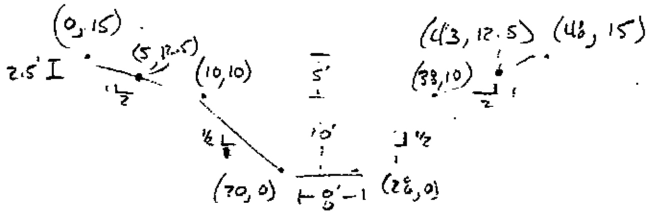
$n_{OB} = 0.12$ ✓
$n_{CHL} = 0.08$ ✓

SOLUTION:

Find channel lengths & slopes:

	L	EL_1	EL_2	S
CP1 → CP2 (A-A)	630'	7800'	7950'	0.24
CP2 → CP3 (B-B)	790'	7650'	7800'	0.19
CP3 → CP4 (C-C)	650	7480'	7650'	0.26
CP4 → CP5 (D-D)	1420'	7210'	7480'	0.19
CP5 → CP6 (E-E)	945'	7110'	7210'	0.11

Find station/elevation for cross sections (RX, RY)



✓

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
→ RX	0	5	10	20	28	38	43	48
→ RY	15	12.5	10	0	0	10	12.5	15

Subject MODIFICATION OF C.S. I-I

Project No. 26389

By RED

Checked By SWR

Task No. 600

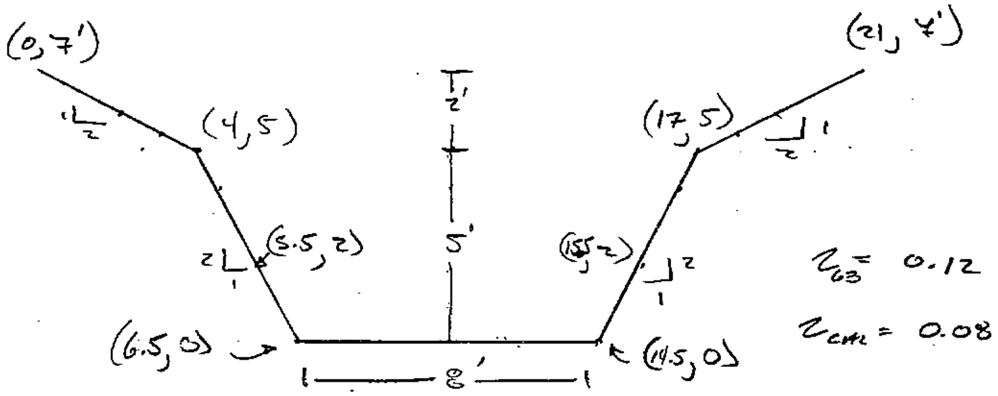
File No.

Date 11/5/97

Date 11/5/97

Sheet 1/1

MODIFICATION OF CROSS SECTION I-I



$n_{OB} = 0.12$

$n_{CHL} = 0.08$

RX	0	4	5.5	6.5	14.5	15.5	17	21
RY	7	5	2	0	0	2	5	7

(* POSSIBLE ATTENUATION W/IN CHANNEL)

Subject Broadmoor - Curve Numbers
Project No. 24389
By SD
Checked By SWR
Task No. 600
File No.
Date 9/27/97
Date 10/08/97
Sheet ~~2~~ 1 of 8

OBJECTIVE:

ESTIMATE CURVE NUMBERS FOR DEVELOPED SUB-BASINS

GIVEN:

SITE MAP (BASIN LOCATIONS)
BASIN AREAS w/ CN'S
Revised by MCB 10/7/97 for Soil Group B (avg. for 1/3 to 1 ac lots = 72 (~~67~~))

SOLUTION:

BASIN ID	(mi²) BASIN AREA	% CN @ ~~74~~ 58	% CN @ ~~85~~ 67 as developed	COMP. CN
✓✓✓✓ 100A	0.048	40	60	~~80.6~~ ~~63.4~~ 66
✓✓✓✓ 100B	0.022	40	60	~~80.6~~ ~~63.4~~ 66
✓✓✓✓ 100C	0.035	0	100	~~85~~ ~~67~~ 72
✓✓✓✓✓ 200A	0.035	15	85	~~83.4~~ ~~65.7~~ 70
✓✓✓✓✓ 200B	0.017	0	100	~~85~~ ~~67~~ 72
✓✓✓✓ 200C	~~0.017~~ 0.051	0	100	~~85~~ ~~67~~ 72
✓✓✓✓✓ 300A	0.049	50	50	~~79.5~~ ~~62.5~~ 65
✓✓✓✓ 300B	0.026	30	70	~~81.7~~ ~~64.3~~ 68
✓✓✓✓✓ 300C	0.06	0	100	~~85~~ ~~67~~ 72
✓✓✓✓ 400A	0.02	0	100	~~85~~ ~~67~~ 72
✓✓✓ 400B	0.01	0	100	~~85~~ ~~67~~ 72
✓✓✓✓ 500A	0.036	0	100	~~85~~ ~~67~~ 72
✓✓✓✓ 500B	0.009	0	100	~~85~~ ~~67~~ 72
✓✓✓✓ 500C	0.015	0	100	~~85~~ ~~67~~ 72

FOR CN = 72 FOR DEVELOPED CONDITIONS

2 of 8

Table 2-2d.—Runoff curve numbers for arid and semiarid rangelands[1]

Cover description		Curve numbers for hydrologic soil group—			
Cover type	Hydrologic condition[2]	A[3]	B	C	D
Herbaceous—mixture of grass, weeds, and low-growing brush, with brush the minor element.	Poor		80	87	93
	Fair		71	81	89
	Good		62	74	85
Oak-aspen—mountain brush mixture of oak brush, aspen, mountain mahogany, bitter brush, maple, and other brush.	Poor		66	74	79
	Fair		48	57	63
	Good		30	41	48
Pinyon-juniper—pinyon, juniper, or both; grass understory.	Poor		75	85	89
	Fair		58	73	80
	Good		41	61	71
Sagebrush with grass understory.	Poor		67	80	85
	Fair		51	63	70
	Good		35	47	55
Desert shrub—major plants include saltbush, greasewood, creosotebush, blackbrush, bursage, palo verde, mesquite, and cactus.	Poor	63	77	85	88
	Fair	55	72	81	86
	Good	49	68	79	84

[1] Average runoff condition, and $I_a = 0.2S$. For range in humid regions, use table 2-2c.

[2] *Poor:* <30% ground cover (litter, grass, and brush overstory).
Fair: 30 to 70% ground cover.
Good: >70% ground cover.

[3] Curve numbers for group A have been developed only for desert shrub.

3 of 8

Table 2-2a.—Runoff curve numbers for urban areas[1]

Cover description		Curve numbers for hydrologic soil group—			
Cover type and hydrologic condition	Average percent impervious area[2]	A	B	C	D
Fully developed urban areas (vegetation established)					
Open space (lawns, parks, golf courses, cemeteries, etc.)[3]:					
Poor condition (grass cover < 50%)		68	79	86	89
Fair condition (grass cover 50% to 75%)		49	69	79	84
Good condition (grass cover > 75%)		39	61	74	80
Impervious areas:					
Paved parking lots, roofs, driveways, etc. (excluding right-of-way)		98	98	98	98
Streets and roads:					
Paved; curbs and storm sewers (excluding right-of-way)		98	98	98	98
Paved; open ditches (including right-of-way)		83	89	92	93
Gravel (including right-of-way)		76	85	89	91
Dirt (including right-of-way)		72	82	87	89
Western desert urban areas:					
Natural desert landscaping (pervious areas only)[4]		63	77	85	88
Artificial desert landscaping (impervious weed barrier, desert shrub with 1- to 2-inch sand or gravel mulch and basin borders)		96	96	96	96
Urban districts:					
Commercial and business	85	89	92	94	95
Industrial	72	81	88	91	93
Residential districts by average lot size:					
1/8 acre or less (town houses)	65	77	85	90	92
1/4 acre	38	61	75	83	87
1/3 acre	30	57	72	81	86
1/2 acre	25	54	70	80	85
1 acre	20	51	68	79	84
2 acres	12	46	65	77	82
5 acres			61 (ASSUMED)		
Developing urban areas					
Newly graded areas (pervious areas only, no vegetation)[5]		77	86	91	94
Idle lands (CN's are determined using cover types similar to those in table 2-2c).					

---

[1] Average runoff condition, and $I_a = 0.2S$.

[2] The average percent impervious area shown was used to develop the composite CN's. Other assumptions are as follows: impervious areas are directly connected to the drainage system, impervious areas have a CN of 98, and pervious areas are considered equivalent to open space in good hydrologic condition. CN's for other combinations of conditions may be computed using figure 2-3 or 2-4.

[3] CN's shown are equivalent to those of pasture. Composite CN's may be computed for other combinations of open space cover type.

[4] Composite CN's for natural desert landscaping should be computed using figures 2-3 or 2-4 based on the impervious area percentage (CN = 98) and the pervious area CN. The pervious area CN's are assumed equivalent to desert shrub in poor hydrologic condition.

[5] Composite CN's to use for the design of temporary measures during grading and construction should be computed using figure 2-3 or 2-4, based on the degree of development (impervious area percentage) and the CN's for the newly graded pervious areas.

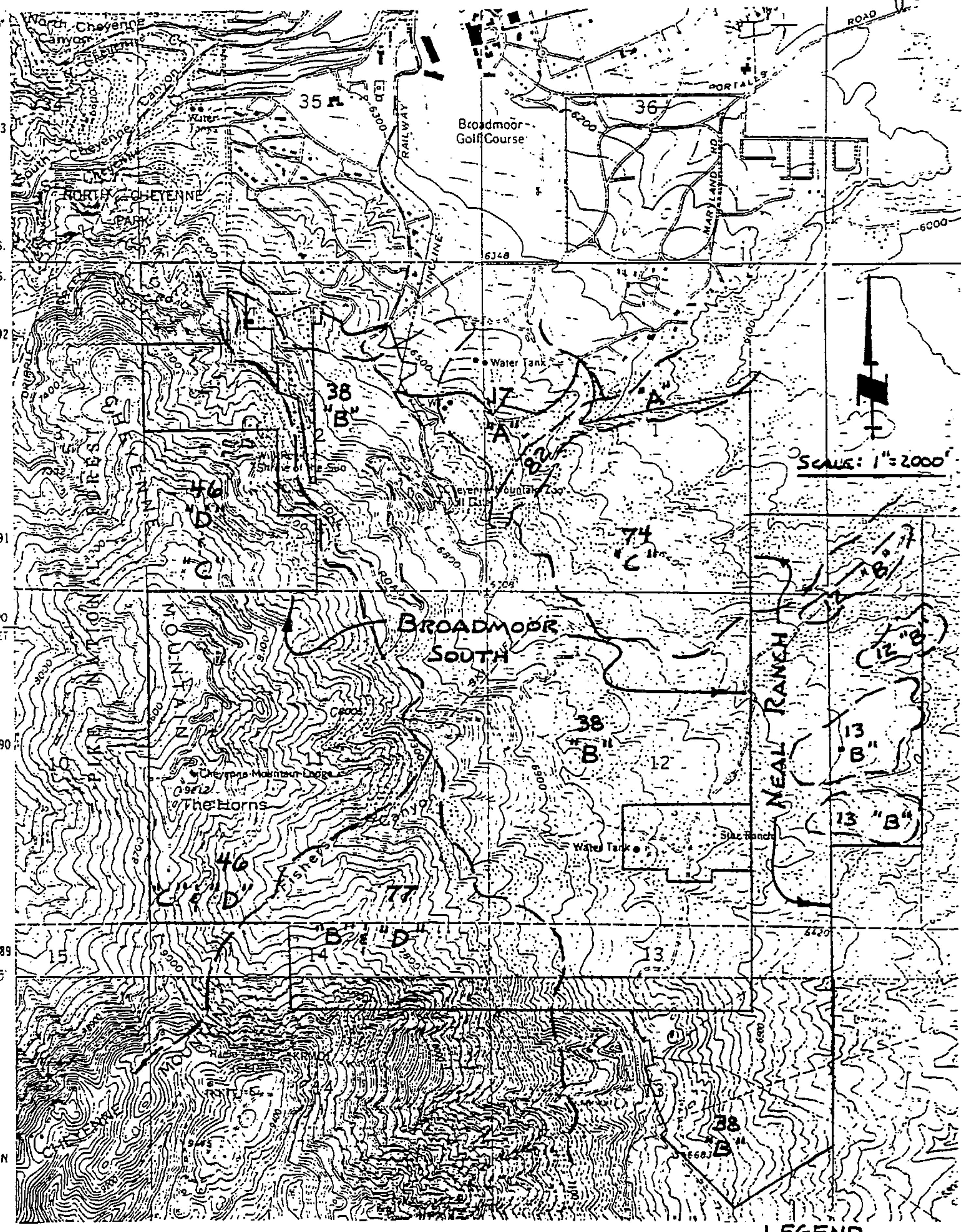


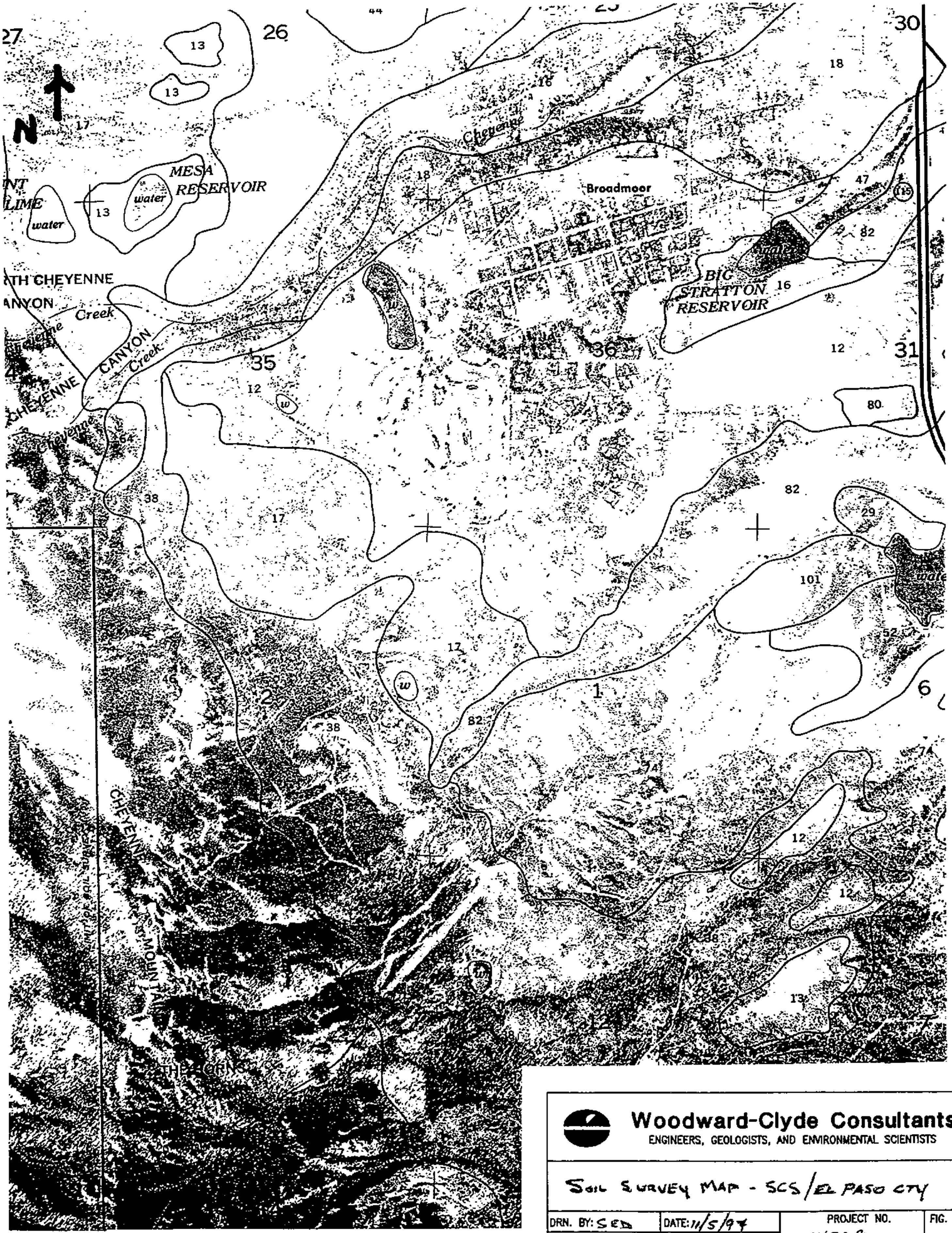
FIGURE II - SOILS CLASSIFICATION MAP

LEGEND

SCS MAP SYMBOL - 38

HYDROLOGIC CLASS ASSUMED - "B"

5 of 8



Woodward-Clyde Consultants

ENGINEERS, GEOLOGISTS, AND ENVIRONMENTAL SCIENTISTS

Soil Survey Map - SCS/El Paso Cty

DRN. BY: SED	DATE: 11/5/94	PROJECT NO. 24389	FIG. NO.
CHK'D BY:	DATE:		

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TABLE 14.--ENGINEERING PROPERTIES AND CLASSIFICATIONS--Continued

Soil name and map symbol	Depth	USDA texture	Classification		Fragments > 3 inches	Percentage passing sieve number--				Liquid limit	Plasticity index
			Unified	AASHTO		4	10	40	200		
	In				Pct					Pct	
Holderness: 34, 35, 36	0-9	Loam	ML	A-4	0-5	80-100	70-100	60-95	50-80	20-40	NP-10
	9-43	Clay loam, clay	CL, CH	A-6, A-7	0-5	80-100	70-100	60-95	50-85	35-65	15-35
	43-60	Gravelly sandy clay loam.	CL, SC, CL-ML, SM-SC	A-6, A-4	0-5	80-100	70-100	60-90	40-65	25-40	5-20
Jarre: 37	0-5	Gravelly sandy loam.	CL-ML, ML, SM, SM-SC	A-4	0-5	85-100	50-100	55-80	45-65	20-30	NP-10
	5-22	Gravelly clay loam, gravelly loam, gravelly sandy clay loam.	CL, SC	A-6, A-2	0-5	85-100	50-100	40-80	25-60	25-40	10-20
	22-60	Very gravelly loam, very gravelly sandy loam.	SM-SC, GM-GC, GP-GC	A-2	0-10	35-85	15-50	10-40	5-30	20-30	5-10
38: Jarre part	0-5	Gravelly sandy loam.	CL-ML, ML, SM, SM-SC	A-4	0-5	85-100	50-100	55-80	45-65	20-30	NP-10
	5-22	Gravelly clay loam, gravelly loam, gravelly sandy clay loam.	CL, SC	A-6, A-2	0-5	85-100	50-100	40-80	25-60	25-40	10-20
	22-60	Very gravelly loam, very gravelly sandy loam.	SM-SC, GM-GC	A-2	0-10	35-85	15-50	10-40	5-30	20-30	5-10
Tecolote part	0-3	Stony loam	GM, ML	A-2, A-4, A-1	25-65	50-75	45-70	30-70	15-60	20-30	NP-5
	3-29	Stony fine sandy loam, stony loam, very gravelly sandy loam.	GM	A-2, A-4, A-1	25-65	50-75	45-70	30-65	15-50	20-30	NP-5
	29-45	Stony clay loam, stony sandy clay loam, extremely gravelly sandy clay loam.	GC, CL	A-2, A-6	25-65	50-75	45-70	35-70	15-55	30-40	10-20
	45-60	Extremely gravelly loamy sand.	GM	A-1	25-65	50-75	30-70	30-50	5-15	---	NP
Keith: 39	0-8	Silt loam	ML, CL-ML	A-4	0	100	100	95-100	85-95	20-35	NP-10
	8-30	Silt loam, silty clay loam.	CL	A-6	0	100	100	95-100	85-100	30-40	10-20
	30-60	Silt loam	ML, CL-ML	A-4	0	100	100	95-100	85-95	20-35	NP-10
Kettle: 40, 41	0-3	Gravelly loamy sand.	SM	A-1, A-2	0-5	80-95	50-100	25-70	10-25	---	NP
	3-40	Gravelly sandy loam.	SC, SM-SC	A-2	0-5	85-100	50-100	25-70	15-35	25-35	5-15
	40-60	Extremely gravelly loamy sand, very gravelly sand.	SM-SC, SP-SC	A-2	0-5	75-90	20-50	10-25	0-15	20-30	5-10

See footnote at end of table.

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Exhibit A-1, continued: Hydrologic soil groups for United States soils

HUNNTON	C
HUNSINGER	B
HUNTERS	B
HUNTERSVILLE	B
HUNTIMER	C
HUNTING	C
HUNTINGTON	B
HUNTMOUNT	B
HUNTROCK	B
HUNTSBURG	D
HUNTSVILLE	B
HUPP	B
HURDS	B
HURLBUT	C
HURLEY	D
HURRICANE	C
HURRY BACK	B
HURRYBACK	B
HURST	D
HURWAL	B
HUSE	D
HUSKA	D
HUSSA	D
HUSSA, CLAYEY SUBSTRATUM	C
HUSSA, MODERATELY WET	C
HUSSA, DRAINED	B
HUSSELL	B
HUSSMAN	D
HUSUM	B
HUTCHINSON	C
HUTCHLEY	D
HUTSON	B
HUTT	D
HUTTON	D
HUXLEY	C
HUYSINK	B
HYALL	C
HYANNIS	B
HYAS	B
HYATTVILLE	C
HYDABURG	D
HYDE	B/D
HYDER	D
HYDRO	C
HYE	B
HYLOC	D
HYMAS	D
HYPRAIRIE	B
HYRUM	B
HYSHAM	D
HYSHOT	D
HYTOP	D
HYZEN	D
IAD	B
IBERIA	D
ICARIA	D
ICENE	D
ICESLEY	D
ICHBOD	D
ICHETUCKNEE	D
ICICLE	B
IDA	B
IDABEL	B
IDAHOME	B
IDAMONT	B
IDEE	C
IDLEWILD	D
IDLEWILD, DRAINED	C
IDMON	B
IGDELL	C
IGERT	C
IGNACIO	C
IGO	D
IGUALDAD	D
IHLEN	B
IJAM	D
ILACHETOMEL	D
ILDECARE	B
ILDEFONSO	B
ILES	C
ILIFF	C
ILIILI	D
ILION	D
ILLABOT	C
ILLAHEE	B
ILLER	B
ILLITO	D
ILTON	C
ILWACO	B
IMA	B
IMBLER	B
IMLAY	D
IMNIG	C
IMMIGRANT	C
IMMOKALEE	B/D
IMMOKALEE, DEPRESSIONAL	D
IMOGENE	D
IMONIL	B
IMPACT	A
IMPERIAL	D
INARAJAN	D
INARAJAN, STRATIFIED SUBSTRATUM	C
INAVALE	A
INCELL	D
INCHAU	C
INCHELIUM	B
INCY	A
INDART	C
INDEX	A
INDIAHOMA	D
INDIAN CREEK	D
INDIANO	C
INDIANOLA	A
INDIO	B
INDLETON	B
INOUS	D
INEZ	D
INFERNAL	D
INGALLS	B
INGENIO	B
INGERSOLL	B
INGRAM	D
INKLER	B
INKOM	D
INKOM, DRAINED	C
INKOSR	D
INKS	D
INKSTER	B
INLOW	C
INMACHUK	D
INMAN	C
INMO	A
INNINGER	C
INPENDENCE	B
INSAK	D
INSIDERT	C
INSKIP	C
INSULA	D
INTERIOR	B
INTON	B
INVERNESS	B
INVERSHIEL	C
INVILLE	B
IO	B
IOLEAU	C
IONA	B
IONIA	B
IOSCO	B
IOSEPA	D
IOTLA	B
IPAGE	A
IPANO	C
IPAVA	B
IPISH	C
IPSON	B
IPSWICH	D
IRA	C
IRAAN	B
IREDELL	C/D
IRELAND	C
IRENE	B
IRETEBA	B
IRIGUL	D
IRIM	C
IRMULCO	B
IROCK	C
IRON BLOSSOM	C
IRON MOUNTAIN	D
IRON RIVER	B
IRONCO	B
IRONDALE	C
IRONDYKE	B
IRONSPRINGS	B
IRONTON	C
IROQUOIS	B/D
IRRAWADDY	C
IRRIGON	C
IRSON	D
IRVINE	D
IRVINGTON	C
IRWIN	D
ISAAC	C
ISABELLA	B
ISAN	A/D
ISANTI	A/D
ISBELL	B
ISELLA	B
ISHI PISHI	C
ISHPEMING	A
ISIDOR	D
ISKNAT	C
ISKNAT, COOL	D
ISLAND	B
ISLES	D
ISLES, SLOUGH	A/D
ISLOTE	B
ISNAY	B
ISOM	C
ISOLDE	A
ISON	B
ISTER	C
ISTOKPOGA	B/D
ITANO	C
ITASCA	B
ITAT	B
ITCA	D
ITHACA	C
ITMANN	C
ITME	A
ITSWOOT	B
IUKA	C
IVA	C
IVAN	B
IVANELL	C
IVANHOE	D
IVEP	B
IVERSEN	C
IVES	B
IVES, WET	D
IVIE	A
IVINS	C
IVYWILD	C
IXIAN	C
IYERS	D
IZAGORA	C
IZAR	D
IZEE	C
IZO	A
IZOO	D
IZUSER	B
JAPU	B
JABU, WET	C
JACAGUAS	B
JACANA	D
JACEE	C
JACINTO	B
JACK CREEK	A
JACKET	C
JACKLAND	D
JACKMAN	B
JACKNIFE	C
JACKPORT	D
JACKPOT	C
JACKS	C
JACKSON	B
JACKTONE	D
JACOE	D
JACOBSEN	D
JACORY	C
JACOT	B
JACQUES	C
JACQUITH	C
JACRATZ	C
JACWIN	B
JADIS	B
JAFA	B
JAGUEYES	B
JAL	B
JALMAR	A
JAMES	D
JAMES CANYON	C
JAMES CANYON, DRAINED	B
JAMESTON	C/D
JANISE	C
JANISE, OVERBLOWN, DRAINED	B
JANSEN	B
JANUDE	B
JANUDE, CLAY SUBSTRATUM	C
JARAB	D
JARBOE	D
JARDIN	D
JAREALES	B
JARITA	C
JARMILLO	B
JAROLA	C
JAROSO	B
JARRE	B
JARRON	D
JARVIS	B
JASCO	D
JASON	D
JASPER	B
JAUCAS	A
JAUCAS, SALINE	C
JAURIGA	B
JAVA	B
JAWBONE	D
JAY	C
JAYAR	C
JAYBEE	D
JAYEL	D
JAYEN	B
JAYNES	D
JEAGER	C
JEAN	A
JEAN LAKE	B
JEANERETTE	D
JEBE	B
JEBO	B
JEDBURG	C
JEDD	C
JEDDITO	C
JEDDITO, SALINE-ALKALI	B
JEDDO	C/D
JEFFERS	B/D
JEFFERSON	B
JEFFREY	B
JEHEMY	D
JEKLEY	C
JELLICO	C
JEMEZ	C
JENA	B
JENKINS	C
JENKINSON	D
JENKS	B
JENNESS	B
JENNINGS	C
JENNY	D
JENOR	C
JERAG	D
JERAULD	D
JERICHO	D
JEROME	D
JERRY	C
JERRYSLU	C
JERU	B
JERVAL	B
JESBEL	D
JESSE CAMP	B
JESSIETOWN	B
JESSO	C
JESSUP	C
JETCOP	D
JETSTER	C
JETT	B
JEVETS	C
JEWETT	B
JIGGS	B
JIGSAW	C
JILSON	D
JIM	C
JIMBO	B
JIMCREEK	C
JIMEK	C
JIMENEZ	C
JIMLAKE	B
JIMMERSON	C
JIMSAGE	B
JIMTOWN	C
JIPPER	B
JIVAS	B
JOACHEM	D
JOB	C
JOBOS	C
JOBPEAK	D
JOCAL	B
JOCITY	B
JOCITY, LOAMY SURFACE	C
JOCKO	B
JODERO	B
JOEL	B
JOEMRE	B
JOENEY	D
JOES	B
JOEVAR	B
JOHNS	C
JOHNSBURG	D
JOHNSON	B
JOHNSTON	D
JOHNSTOWN	B
JOHNSWOOD	B
JOHNTOM	D
JOICE	D
JOINER	B
JOKODOWSKI	D
JOLAN	C
JOLIET	D
JOLLY	C
JOMALE	B
JONAS	B
JONATHAN	B
JONCA	C
JONDA	B
JONES	B
JONESVILLE	B

NOTES: TWO HYDROLOGIC SOIL GROUPS SUCH AS B/C INDICATES THE DRAINED/UNDRAINED SITUATION.
MODIFIERS SHOWN, E.G., BEDROCK SUBSTRATUM, REFER TO A SPECIFIC SOIL SERIES PHASE FOUND IN SOIL MAP LEGEND.

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Exhibit A-1, continued: Hydrologic soil groups for United States soils

SUNYA	D	SWANTOWN	D	TACOMA	D	TANQUE	B	TEHAMA	C
SUN	D	SWANVILLE	C	TACONIC	C/D	TANSEM	B	TEHRAN	A
SUNAPEE	B	SWANWICK	D	TACOOSH	B/D	TANTALUS	B	TEIGEN	C
SUNBURG	B	SWAPPS	C	TADLOCK	B	TANTILE	C/D	TEJA	D
SUNBURST	C	SWARTSWOOD	C	TAFFON	B	TANWAX	D	TEJABE	D
SUNBURY	B	SWARTZ	D	TAFOYA	C	TANWAX, DRAINED	C	TEJANA	B
SUNCITY	D	SWASEY	D	TAFT	C	TANYARD	C	TEKENINK	B
SUNCOOK	A	SWASTIKA	C	TAFTOWN	B	TAOPI	B	TEKISON	C
SUND	C	SWAUK	D	TAFUNA	A	TAPCO	D	TEKLANIKA	A
SUNDANCE	B	SWAYNE	C	TAGGART	C	TAPIA	B	TEKOA	C
SUNDAY	A	SWEATMAN	C	TAGLAKE	B	TAPICITOES	D	TEKOA, EXTREMELY	B
SUNDELL	B	SWEDE	B	TAHKENITCH	B	TAPPAN	B/D	STONY	
SUNDOWN	A	SWEEN	C	TAHOMA	B	TARA	B	TELA	B
SUNEV	B	SWEENEY	B	TAHOULA	D	TARBORO	A	TELCHER	B
SUNFIELD	B	SWEET	C	TAHQUATS	B	TARGHEE	C	TELECAN	B
SUNLIGHT	D	SWEETAPPLE	B	TAINTOR	C/D	TARKINGTON	C	TELEFONO	C
SUNNYHAY	D	SWEETGRASS	B	TAJO	C	TARKIO	D	TELEMON	D
SUNNYSIDE	B	SWEETWATER	D	TAKEUCHI	C	TARKLIN	C	TELEPHONE	D
SUNNYVALE	C	SWEITBERG	C	TAKILMA	B	TARLOC	B	TELESCOPE	A
SUNRAY	B	SWEITING	C	TAKOTNA	B	TARNACH	D	TELFER	A
SUNRISE	C	SWEN	C	TAKPOCHAO	D	TARNAV	B	TELFERNER	D
SUNSET	B	SWENODA	B	TALAG	D	TARPLEY	D	TELL	B
SUNSHINE	C	SWIFT	B	TALAMANTES	B	TARR	A	TELLER	B
SUNSWEET	C	SWIFT CREEK	B	TALANTE	D	TARRANT	D	TELLICO	B
SUNUP	D	SWIFTON	B	TALAPUS	B	TARRETE	D	TELLMAN	B
SUNY	D	SWIMLEY	C	TALBOTT	C	TARRYALL	C	TELLURA	C
SUOMI	C	SWIMS	B	TALCO	D	TARRYTOWN	C	TELOS	C
SUP	B	SWINGLER	B	TALCOT	B/D	TASAYA	C	TELSTAD	C
SUPAN	B	SWINGLER, WET,	C	TALIHINA	D	TASCOSA	B	TEMAN	B
SUPERIOR	D	STRONGLY SALINE		TALKEETNA	B	TASSEL	D	TEMBLOR	D
SUPERSTITION	A	SWINGLER, WET	C	TALLA	C	TASSELMAN	D	TEMESCAL	D
SUPERVISOR	C	SWINK	D	TALLAC	B	TASSO	B	TEMO	C
SUPPLEE	B	SWINOMISH	C	TALLADEGA	C	TATAI	C	TEMPLE	C
SUR	C	SWINT	B	TALLAPOOSA	C	TATE	B	TEMPLETON	B
SURFSIDE	D	SWISBOB	D	TALLEYVILLE	B	TATERHEAP	B	TEMVIK	B
SURGEM	C	SWISSHELM	B	TALLOWBOX	C	TATIYEE	C	TENABO	D
SURGH	B	SWISSTAG	B	TALLS	B	TATLUM	D	TENAHA	B
SURNUF	B	SWISSVALE	D	TALLULA	B	TATOUCHE	B	TENAS	C
SURPLUS	C	SWITCHBACK	C	TALLY	B	TATTON	D	TENCEE	D
SURPRISE	B	SWITZERLAND	B	TALMAGE	B	TATUM	B	TENDOY	D
SURRENCY	D	SWOPE	C	TALMO	A	TAUNTON	C	TENERIFFE	A
SURRETT	C	SWORMVILLE	C	TALMOON	D	TAVARES	A	TENEX	B
SURVEYORS	B	SWYGERT	C	TALOKA	D	TAWAH	B	TENINO	C
SURVYA	C	SYBLON	D	TALPA	D	TAWAS	A/D	TENMILE	C
SUSANNA	C/D	SYCAMORE,	B	TALQUIN	B/D	TAWCAW	C	TENNO	D
SUSANVILLE	D	MODERATELY WET,		TALUCE	D	TAYLOR	C	TENORIO	B
SUSIE CREEK	C	SALINE		TAMA	B	TAYLOR CREEK	C	TENOT	C
SUSITNA	B	SYCAMORE,	C	TAMAHA	D	TAYLORSFLAT	B	TENPIN	D
SUSQUEHANNA	D	MODERATELY WET,		TAMALCO	D	TAYLORSFLAT,	C	TENRAG	B
SUTA	B	CLAYEY SUBSTRATUM		TAMALPAIS	C	SALINE-ALKALI		TENSAS	D
SUTCLIFF	B	SYCAMORE,	C	TAMANEEN	B	TAYLORSVILLE	C	TENSED	C
SUTHER	C	MODERATELY WET		TAMBA	D	TAZLINA	A	TENSLEEP	B
SUTHERLAND	D	SYCAMORE, DRAINED	B	TAMELY	B	TEAGULF	C	TENSHOIR	B
SUTHERLIN	C	SYCAMORE, FLOODED	C	TAMFLAT	D	TEAKEAN	B	TENVORRD	D
SUTKIN	B	SYCAMORE, CLAY	B	TAMFORD	D	TEALSON	D	TEO	B
SUTLEY	B	SUBSTRATUM		TAMMANY CREEK	B	TEALWHIT	D	TEOCULLI	B
SUTPHEN	C	SYCAN	A	TAMWING	B	TEANAWAY	B	TEPETE	D
SUTRO	C	SYCLE	B	TAMP	B	TEAPO	C	TEQUESTA	B/D
SUTTLER	B	SYCOLINE	D	TAMPICO	B	TEASDALE	B	TERADA	B
SUTTON	B	SYENITE	C	TANAMA	D	TEASPOON	D	TERBIES	B
SUVER	D	SYLACAUGA	D	TANANA	D	TEBAY	B	TERENCE	B
SUWANEE	A	SYLCO	C	TANANA, THAWED	B	TEBBS	B	TERESA	D
SVEA	B	SYLVAN	B	TANANA, MODERATELY	C	TEBO	B	TERINO	D
SVENSEN	B	SYLVANIAN	C	WET		TECHADO	D	TERLAN	D
SVERDRUP	B	SYLVESTER	B	TANASEE	B	TECHICK	B	TERLCO	B
SWAGER	C	SYLVIA	C	TANAZZA	B	TECO	B	TERLINGUA	D
SWAINOW	B	SYMCO	C	TANBARK	D	TECOLOTE	B	TERMINAL	D
SWAKANE	D	SYMERTON	B	TANDY	D	TECOMAR	D	TERMO	D
SWALER	D	SYNAREP	B	TANEUM	B	TECOPA	D	TEROMOTE	B
SWALESILVER	D	SYRACUSE	B	TANEY	C	TEDROW	B	TEROUGE	D
SWAMPYDRAW	B	SYRENE	B/D	TANGAIR	C	TEEL	B	TERRA CEIA	B/D
SWAN	D	SYRETT	C	TANGI	C	TEELER	B	TERRA CEIA, TIDAL	D
SWANBOY	D	TABECHEDING	C	TANGLE	C	TEEMAT	B	TERRA CEIA,	D
SWANDAD	B	TABERNASH	B	TANNA	D	TEESTO	D	FREQUENTLY	
SWANLAKE	B	TABLE MOUNTAIN	B	TANNAHILL	B	TEETERS	C	FLOODED	
SWANNER	D	TABLER	D	TANNER	C	TEEWINOT	D	TERRAD	C
SWANSEA	D	TABOR	D	TANNER, LOW	D	TEFTON	C	TERRETON	D
SWANSON	C	TACAN	B	PRECIPITATION		TEGURO	D	TERRETON, STONY	C
SWANTON	C/D	TACHI	D	TANOE	B	TEHACHAPI	C	TERRIL	B

NOTES: TWO HYDROLOGIC SOIL GROUPS SUCH AS B/C INDICATES THE DRAINED/UNDRAINED SITUATION.
MODIFIERS SHOWN, E.G., BEDROCK SUBSTRATUM, REFER TO A SPECIFIC SOIL SERIES PHASE FOUND IN SOIL MAP LEGEND.

Subject BROADMOOR - HYDROLOGIC PARAMETERS

Project No. 24389

By [illegible]

Checked By SWR

Task No. 600

File No.

Date 9/23/97

Date 10/08/97

Sheet 1 of 28

OBJECTIVE:

DEVELOP HYDROLOGIC PARAMETERS FOR SUB-BASINS ASSOCIATED w/ FISCHERS CANYON DRAINAGEWAY

GIVEN:

SUTTE TOPO (1:2400)
TR 55 METHODOLOGY FOR t_c/t_t CALC'S
MANNING'S n BREAKDOWNS (ASSUME n = 0.10 ROCK/FOREST;
APPROXIMATED AVERAGE VELOCITIES - NAT'L CHANNELS

SOLUTION:

SEE ATTACHED EXCEL WORKSHEET (@ FILE H:\[illegible].XLS)

Project: Broadmoor-Fischers Canyon
Project #: 24389

Objective: Develop hydrologic parameters for sub-basins associated w/ Fischers Canyon development

Hydrologic Parameters:
Undeveloped

Sub-Basin (ID)	Area (acres)	Area (mi²)	Length (feet)	Length(10-85) (feet)	Elevation (10%) (feet)	Elevation (85%) (feet)	Slope (10-85) (ft/mi)	Slope(10-85) (ft/ft)	Tt1 (hr)	Tt2 (hr)	Tt3 (hr)	Tc₁ (hr)	Tc₂ (hr)	Tc₃ (hr)
100A	30.8	0.048	1500	1125	6664	6784	563.2	0.107	0.64	0.01	0.10	0.76	0.27	0.07
100B	14.3	0.022	1350	1013	6666	6796	677.6	0.128	0.82	0.05	0.05	0.93	0.26	0.06
100C	22.3	0.035	1800	1350	6538	6610	281.6	0.053	-	-	0.07	0.07	0.29	0.10
200A	22.1	0.035	1650	1238	6640	6762	520.3	0.099	0.82	0.06	0.07	0.95	0.28	0.08
200B	11.1	0.017	1650	1238	6640	6762	520.3	0.099	0.73	0.11	0.04	0.88	0.28	0.08
200C	11.1	~~0.017~~ 0.021	1650	1238	6640	6762	520.3	0.099	0.82	0.11	-	0.93	0.28	0.08
300A	31.5	0.049	2100	1575	6684	6870	623.5	0.118	0.73	0.03	0.08	0.84	0.31	0.09
300B	16.6	0.026	1150	863	6680	6780	611.8	0.116	0.79	0.05	0.08	0.92	0.25	0.05
300C	38.3	0.060	1750	1313	6498	6624	506.7	0.096	-	-	0.07	0.07	0.29	0.08
0.020 400A	19.0	~~0.030~~	3450	2588	6484	6784	612.1	0.116	-	-	0.32	0.32	0.41	0.13
0.010 400B	19.0	~~0.030~~	3450	2588	6484	6784	612.1	0.116	-	-	0.32	0.32	0.41	0.13
500A	23.0	0.036	2100	1575	6654	6890	791.2	0.150	0.57	0.02	0.06	0.65	0.31	0.08
0.009 500B	15.7	~~0.025~~	600	450	6520	6608	1032.5	0.196	0.82	0.05	0.04	0.91	0.21	0.03
500C	9.8	0.015	600	450	6520	6608	1032.5	0.196	0.82	0.05	0.04	0.91	0.21	0.03

Tc₁ -calculated via TR-55 methodology
Tc₂ -calculated via SCS-Denver basin methodology
Tc₃ -calculated via Kirpich's formula

Developed

Sub-Basin (ID)	Area (acres)	Area (mi²)	Length (feet)	Length(10-85) (feet)	Elevation (10%) (feet)	Elevation (85%) (feet)	Slope (10-85) (ft/mi)	Slope(10-85) (ft/ft)	Tt1 (hr)	Tt2 (hr)	Tt3 (hr)	Tc₁ (hr)	Tc₂ (hr)	Tc₃ (hr)	Tl (hr)
100A	30.8	0.048	1500	1125	6664	6784	563.2	0.107	0.55	0.01	0.09	0.65	0.23	0.06	0.138
100B	14.3	0.022	1350	1013	6666	6796	677.6	0.128	0.70	0.04	0.05	0.80	0.22	0.05	0.132
100C	22.3	0.035	1800	1350	6538	6610	281.6	0.053	-	-	0.06	0.06	0.25	0.09	0.150
200A	22.1	0.035	1650	1238	6640	6762	520.3	0.099	0.70	0.06	0.06	0.82	0.24	0.07	0.144
200B	11.1	0.017	1650	1238	6640	6762	520.3	0.099	0.63	0.10	0.03	0.75	0.24	0.07	0.144
200C	11.1	~~0.017~~ 0.021	1650	1238	6640	6762	520.3	0.099	0.70	0.10	-	0.80	0.24	0.07	0.144
300A	31.5	0.049	2100	1575	6684	6870	623.5	0.118	0.63	0.02	0.07	0.72	0.27	0.07	0.162
300B	16.6	0.026	1150	863	6680	6780	611.8	0.116	0.68	0.04	0.07	0.79	0.21	0.05	0.126
300C	38.3	0.060	1750	1313	6498	6624	506.7	0.096	-	-	0.06	0.06	0.25	0.07	0.150
0.020 400A	19.0	~~0.030~~	3450	2588	6484	6784	612.1	0.116	-	-	0.27	0.27	0.35	0.11	0.210
0.010 400B	19.0	~~0.030~~	3450	2588	6484	6784	612.1	0.116	-	-	0.27	0.27	0.35	0.11	0.210
500A	23.0	0.036	2100	1575	6654	6890	791.2	0.150	0.49	0.02	0.05	0.56	0.27	0.07	0.162
0.009 500B	15.7	~~0.025~~	600	450	6520	6608	1032.5	0.196	0.70	0.04	0.04	0.78	0.18	0.02	0.108
500C	9.8	0.015	600	450	6520	6608	1032.5	0.196	0.70	0.04	0.04	0.78	0.18	0.02	0.108

Assumes ~86% reduction in travel time based on approximate ~86% reduction between developed and existing terrain conditions.

Lag Time = $Tc_2 * 0.60$

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Project: Broadmoor-Fischers Canyon
Project #: 24389

Objective: Develop hydrologic parameters for sub-basins associated w/ Fischers Canyon development

Hydrologic Parameters:

	Sub-Basin (ID)	Area (acres)	Area (mi²)	Length (feet)	Length(10-85) (feet)	Elevation (10%) (feet)	Elevation (85%) (feet)	Slope (10-85) (ft/mi)	Slope(10-85) (ft/ft)	tc
✓	100A	30.8		1500	1125	6664	6784			
✓	100B	14.3		1350	1013	6666	6796			
✓	100C	22.3		1800	1350	6538	6610			
✓	200	41.3		1650	1238	6640	6762			
✓	300-A	31.5		2100	1575	6684	6870			
✓	300-B	16.6		1150	863	6680	6780			
✓	300-C	38.3		1750	1313	6498	6624			
✓	400	19.6		3450	2588	6484	6784			
✓	500-A	32.8		2100	1575	6654	6890			
✓	500-B	15.7		600	450	6520	6608			

V

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Project: Broadmoor-Fischers Canyon
Project #: 24389

Objective: Develop time of travel/concentration for individual basins

Sheet Flow		
1. Surface Description	Rck/Frst	
2. Manning's Roughness (n)	0.8	
3. Flow Length (total<=300 ft)	300	
4. Two-Year Rainfall (P2)	1.7	
5. Land Slope (S)	0.366667	
6. Tt = $\frac{0.007(nL)^{0.8}}{(P2)^{0.5}*(S)^{0.4}}$	0.64	*0.64*
Shallow Concentrated Flow		
7. Surface Description	Rck/Frst	
8. Flow Length (L)	500	
9. Watercourse Slope (S)	0.58	
10. Average Velocity (V)	10	
11. Tt = $\frac{L}{3600V}$	0.01	*0.01*
Channel Flow		
12. Cross Sectional Flow Area (A)	-	
13. Wetted Perimeter (Pw)	-	
14. Hydraulic Radius (R=A/Pw)	-	
15. Channel Slope (S)	6.00	
16. Manning's Roughness (n)	0.8	
17. Velocity $\frac{1.49R^{2/3}S^{1/2}}{n}$	4.00	
18. Flow Length (L)	1500	
19. Tt = $\frac{L}{3600V}$	0.10	*0.10*
20. Total Time of Concentration		**0.76**

Elev.0	Elev.1
7100	7210
6810	7100
6644	6810

per table 5.7.1

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Project: Broadmoor-Fischers Canyon
Project #: 24389

Objective Develop time of travel/concentration for individual basins

Sheet Flow		
1. Surface Description	Rck/Frst	
2. Manning's Roughness (n)	0.8	
3. Flow Length (total<=300 ft)	300	
4. Two-Year Rainfall (P2)	1.7	
5. Land Slope (S)	0.2	
6. Tt = $\frac{.007(nL)^{0.8}}{(P2)^{0.5}*(S)^{0.4}}$	0.82	*0.82*
Shallow Concentrated Flow		
7. Surface Description	Rck/Frst	
8. Flow Length (L)	1400	
9. Watercourse Slope (S)	0.21	
10. Average Velocity (V)	7.5	
11. Tt = $\frac{L}{3600V}$	0.05	*0.05*
Channel Flow		
12. Cross Sectional Flow Area (A	-	
13. Wetted Perimeter (Pw)	-	
14. Hydraulic Radius (R=A/Pw)	-	
15. Channel Slope (S)	0.13037	
16. Manning's Roughness (n)	0.8	
17. Veloci $\frac{.49R^{2/3}S^{1/2}}{n}$	7.00	
18. Flow Length (L)	1350	
19. Tt = $\frac{L}{3600V}$	0.05	*0.05*
20. Total Time of Concentration		**0.93**

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Elev.0	Elev.1
7120	7180
6820	7120
6644	6820

per table 5.7.1

Project: Broadmoor-Fischers Canyon
Project #: 24389

Objective Develop time of travel/concentration for individual basins

Sheet Flow		
1. Surface Description	Rck/Frst	
2. Manning's Roughness (n)	0.8	
3. Flow Length (total<=300 ft)	-	
4. Two-Year Rainfall (P2)	1.7	
5. Land Slope (S)	-	
6. Tt = $\frac{.007(nL)^{0.8}}{(P2)^{0.5}*(S)^{0.4}}$	-	-
Shallow Concentrated Flow		
7. Surface Description	Rck/Frst	
8. Flow Length (L)	-	
9. Watercourse Slope (S)	-	
10. Average Velocity (V)	-	
11. Tt = $\frac{L}{3600V}$	-	-
Channel Flow		
12. Cross Sectional Flow Area (A	-	
13. Wetted Perimeter (Pw)	-	
14. Hydraulic Radius (R=A/Pw)	-	
15. Channel Slope (S)	0.07	
16. Manning's Roughness (n)	0.8	
17. Veloci $\frac{.49R^{2/3}S^{1/2}}{n}$	7.00	
18. Flow Length (L)	1800	
19. Tt = $\frac{L}{3600V}$	0.07	*0.07*
20. Total Time of Concentration		**0.07**

Elev.0	Elev.1
-	-
-	-
6518	6644

per table 5.7.1

Project: Broadmoor-Fischers Canyon
Project #: 24389

Objective Develop time of travel/concentration for individual basins

Sheet Flow		
1. Surface Description	Rck/Frst	
2. Manning's Roughness (n)	0.8	
3. Flow Length (total<=300 ft)	300	
4. Two-Year Rainfall (P2)	1.7	
5. Land Slope (S)	0.2	
6. Tt = .007(nL)^0.8	0.82	*0.82*
(P2)^0.5*(S)^0.4		
Shallow Concentrated Flow		
7. Surface Description	Rck/Frst	
8. Flow Length (L)	1400	
9. Watercourse Slope (S)	0.174286	
10. Average Velocity (V)	6	
11. Tt = L	0.06	*0.06*
3600V		
Channel Flow		
12. Cross Sectional Flow Area (A	-	
13. Wetted Perimeter (Pw)	-	
14. Hydraulic Radius (R=A/Pw)	-	
15. Channel Slope (S)	0.157576	
16. Manning's Roughness (n)	0.8	
17. Veloci $.49R^{2/3}S^{1/2}$	7.00	
n		
18. Flow Length (L)	1650	
19. Tt = L	0.07	*0.07*
3600V		
20. Total Time of Concentration		**0.95**

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Elev.0	Elev.1
7030	7090
6786	7030
6526	6786

per table 5.7.1

Project: Broadmoor-Fischers Canyon
Project #: 24389

Objective Develop time of travel/concentration for individual basins

Sheet Flow		
1. Surface Description	Rck/Frst	
2. Manning's Roughness (n)	0.8	
3. Flow Length (total<=300 ft)	300	
4. Two-Year Rainfall (P2)	1.7	
5. Land Slope (S)	0.266667	
6. Tt = $\frac{.007(nL)\text{^}0.8}{(P2)\text{^}0.5*(S)\text{^}0.4}$	0.73	*0.73*
Shallow Concentrated Flow		
7. Surface Description	Rck/Frst	
8. Flow Length (L)	800	
9. Watercourse Slope (S)	0.25	
10. Average Velocity (V)	8	
11. Tt = $\frac{L}{3600V}$	0.03	*0.03*
Channel Flow		
12. Cross Sectional Flow Area (A -		
13. Wetted Perimeter (Pw) -		
14. Hydraulic Radius (R=A/Pw) -		
15. Channel Slope (S)	0.110	
16. Manning's Roughness (n)	0.8	
17. Veloci $\frac{.49R^{2/3}S^{1/2}}{n}$	7.00	
18. Flow Length (L)	2100	
19. Tt = $\frac{L}{3600V}$	0.08	*0.08*
20. Total Time of Concentration		**0.84**

Elev.0	Elev.1
7100	7180
6900	7100
6670	6900

per table 5.7.1

Project: Broadmoor-Fischers Canyon
Project #: 24389

Objective Develop time of travel/concentration for individual basins

Sheet Flow		
1. Surface Description	Rck/Frst	
2. Manning's Roughness (n)	0.8	
3. Flow Length (total<=300 ft)	300	
4. Two-Year Rainfall (P2)	1.7	
5. Land Slope (S)	0.216667	
6. Tt = $\frac{.007(nL)\text{^}0.8}{(P2)\text{^}0.5*(S)\text{^}0.4}$	0.79	*0.79*
Shallow Concentrated Flow		
7. Surface Description	Rck/Frst	
8. Flow Length (L)	1000	
9. Watercourse Slope (S)	0.176	
10. Average Velocity (V)	5.5	
11. Tt = $\frac{L}{3600V}$	0.05	*0.05*
Channel Flow		
12. Cross Sectional Flow Area (A	-	
13. Wetted Perimeter (Pw)	-	
14. Hydraulic Radius (R=A/Pw)	-	
15. Channel Slope (S)	0.073043	
16. Manning's Roughness (n)	0.8	
17. Veloci $\frac{.49R^{2/3}S^{1/2}}{n}$	4.00	
18. Flow Length (L)	1150	
19. Tt = $\frac{L}{3600V}$	0.08	*0.08*
20. Total Time of Concentration		**0.92**

Elev.0	Elev.1
6930	6995
6754	6930
6670	6754

per table 5.7.1

Project: Broadmoor-Fischers Canyon
Project #: 24389

Objective Develop time of travel/concentration for individual basins

Sheet Flow		
1. Surface Description	Rck/Frst	
2. Manning's Roughness (n)	-	
3. Flow Length (total<=300 ft)	-	
4. Two-Year Rainfall (P2)	-	
5. Land Slope (S)	-	
6. Tt = $\frac{.007(nL)^{0.8}}{(P2)^{0.5}*(S)^{0.4}}$	-	-
Shallow Concentrated Flow		
7. Surface Description	Rck/Frst	
8. Flow Length (L)	-	
9. Watercourse Slope (S)	-	
10. Average Velocity (V)	-	
11. Tt = $\frac{L}{3600V}$	-	-
Channel Flow		
12. Cross Sectional Flow Area (A	-	
13. Wetted Perimeter (Pw)	-	
14. Hydraulic Radius (R=A/Pw)	-	
15. Channel Slope (S)	0.105714	
16. Manning's Roughness (n)	0.8	
17. Veloci $\frac{.49R^{2/3}S^{1/2}}{n}$	7.00	
18. Flow Length (L)	1750	
19. Tt = $\frac{L}{3600V}$	0.07	*0.07*
20. Total Time of Concentration		**0.07**

Elev.0	Elev.1
-	-
-	-
6485	6670

per table 5.7.1

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Project: Broadmoor-Fischers Canyon
Project #: 24389

Objective Develop time of travel/concentration for individual basins

Sheet Flow		
1. Surface Description	Rck/Frst	
2. Manning's Roughness (n)	-	
3. Flow Length (total<=300 ft)	-	
4. Two-Year Rainfall (P2)	-	
5. Land Slope (S)	-	
6. Tt = .007(nL)^0.8 / (P2)^0.5*(S)^0.4	-	-
Shallow Concentrated Flow		
7. Surface Description	Rck/Frst	
8. Flow Length (L)	-	
9. Watercourse Slope (S)	-	
10. Average Velocity (V)	-	
11. Tt = L / 3600V	-	-
Channel Flow		
12. Cross Sectional Flow Area (A	-	
13. Wetted Perimeter (Pw)	-	
14. Hydraulic Radius (R=A/Pw)	-	
15. Channel Slope (S)	0.061159	
16. Manning's Roughness (n)	0.8	
17. Veloci $\frac{.49R^{2/3}S^{1/2}}{n}$	3.00	
18. Flow Length (L)	3450	
19. Tt = L / 3600V	0.32	*0.32*
20. Total Time of Concentration		**0.32**

Elev.0	Elev.1
-	-
-	-
6644	6855

per table 5.7.1

Project: Broadmoor-Fischers Canyon
Project #: 24389

Objective Develop time of travel/concentration for individual basins

Sheet Flow		
1. Surface Description	Rck/Frst	
2. Manning's Roughness (n)	0.8	
3. Flow Length (total<=300 ft)	300	
4. Two-Year Rainfall (P2)	1.7	
5. Land Slope (S)	0.5	
6. Tt = $\frac{.007(nL)^{0.8}}{(P2)^{0.5}*(S)^{0.4}}$	0.57	*0.57*
Shallow Concentrated Flow		
7. Surface Description	Rck/Frst	
8. Flow Length (L)	700	
9. Watercourse Slope (S)	0.314286	
10. Average Velocity (V)	9	
11. Tt = $\frac{L}{3600V}$	0.02	*0.02*
Channel Flow		
12. Cross Sectional Flow Area (A	-	
13. Wetted Perimeter (Pw)	-	
14. Hydraulic Radius (R=A/Pw)	-	
15. Channel Slope (S)	0.11619	
16. Manning's Roughness (n)	0.8	
17. Veloci $\frac{.49R^{2/3}S^{1/2}}{n}$	7.00	
18. Flow Length (L)	2100	
19. Tt = $\frac{L}{3600V}$	0.08	*0.08*
20. Total Time of Concentration		**0.67**

Elev.0	Elev.1
7090	7240
6870	7090
6626	6870

per table 5.7.1

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Project: Broadmoor-Fischers Canyon
Project #: 24389

Objective Develop time of travel/concentration for individual basins

Sheet Flow		
1. Surface Description	Rck/Frst	
2. Manning's Roughness (n)	0.8	
3. Flow Length (total<=300 ft)	300	
4. Two-Year Rainfall (P2)	1.7	
5. Land Slope (S)	0.2	
6. Tt = $\frac{.007(nL)^{0.8}}{(P2)^{0.5}*(S)^{0.4}}$	0.82	*0.82*
Shallow Concentrated Flow		
7. Surface Description	Rck/Frst	
8. Flow Length (L)	1000	
9. Watercourse Slope (S)	0.142	
10. Average Velocity (V)	6	
11. Tt = $\frac{L}{3600V}$	0.05	*0.05*
Channel Flow		
12. Cross Sectional Flow Area (A	-	
13. Wetted Perimeter (Pw)	-	
14. Hydraulic Radius (R=A/Pw)	-	
15. Channel Slope (S)	0.063333	
16. Manning's Roughness (n)	0.8	
17. Veloci $\frac{.49R^{2/3}S^{1/2}}{n}$	4.00	
18. Flow Length (L)	600	
19. Tt = $\frac{L}{3600V}$	0.04	*0.04*
20. Total Time of Concentration		**0.91**

Elev.0	Elev.1
6720	6780
6578	6720
6540	6578

per table 5.7.1

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VELOCITY / SLOPE - SHALLOW CONC'D

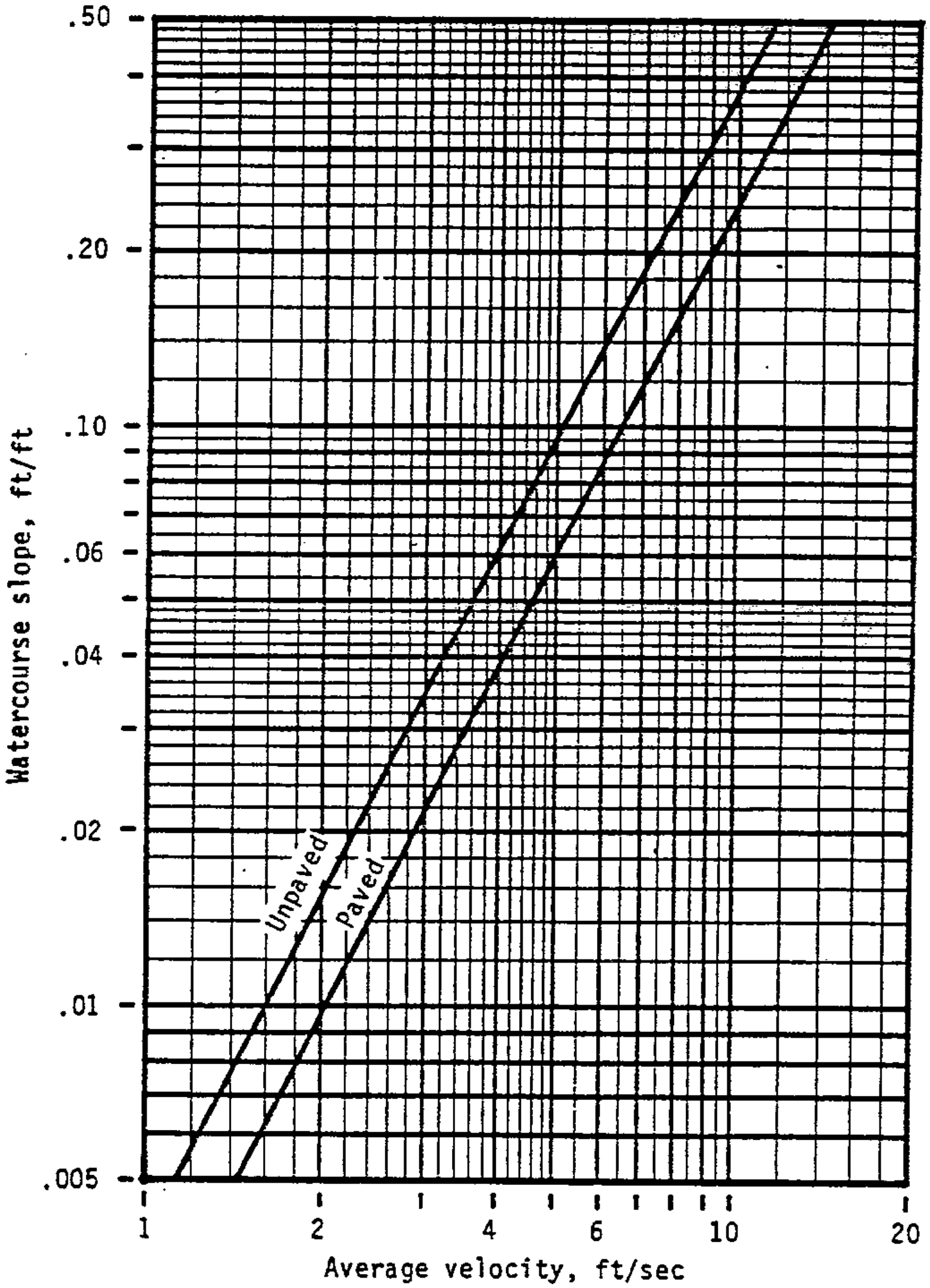

Figure 3-1.—Average velocities for estimating travel time for shallow concentrated flow.

Sheet flow

Sheet flow is flow over plane surfaces. It usually occurs in the headwater of streams. With sheet flow, the friction value (Manning's n) is an effective roughness coefficient that includes the effect of raindrop impact; drag over the plane surface; obstacles such as litter, crop ridges, and rocks; and erosion and transportation of sediment. These n values are for very shallow flow depths of about 0.1 foot or so. Table 3-1 gives Manning's n values for sheet flow for various surface conditions.

For sheet flow of less than 300 feet, use Manning's kinematic solution (Overton and Meadows 1976) to compute T_t:

$$T_t = \frac{0.007\,(nL)^{0.8}}{(P_2)^{0.5}\, s^{0.4}} \qquad \text{[Eq. 3-3]}$$

Table 3-1.—Roughness coefficients (Manning's n) for sheet flow

Surface description	n[1]
Smooth surfaces (concrete, asphalt, gravel, or bare soil)	0.011
Fallow (no residue)	0.05
Cultivated soils:	
Residue cover ≤20%	0.06
Residue cover >20%	0.17
Grass:	
Short grass prairie	0.15
Dense grasses[2]	0.24
Bermudagrass	0.41
Range (natural)	0.13
Woods:[3]	
Light underbrush	0.40
Dense underbrush	0.80

[1] The n values are a composite of information compiled by Engman (1986).

[2] Includes species such as weeping lovegrass, bluegrass, buffalo grass, blue grama grass, and native grass mixtures.

[3] When selecting n, consider cover to a height of about 0.1 ft. This is the only part of the plant cover that will obstruct sheet flow.

where

T_t = travel time (hr),
n = Manning's roughness coefficient (table 3-1),
L = flow length (ft),
P_2 = 2-year, 24-hour rainfall (in), and
s = slope of hydraulic grade line (land slope, ft/ft).

This simplified form of the Manning's kinematic solution is based on the following: (1) shallow steady uniform flow, (2) constant intensity of rainfall excess (that part of a rain available for runoff), (3) rainfall duration of 24 hours, and (4) minor effect of infiltration on travel time. Rainfall depth can be obtained from appendix B.

Shallow concentrated flow

After a maximum of 300 feet, sheet flow usually becomes shallow concentrated flow. The average velocity for this flow can be determined from figure 3-1, in which average velocity is a function of watercourse slope and type of channel. For slopes less than 0.005 ft/ft, use equations given in appendix F for figure 3-1. Tillage can affect the direction of shallow concentrated flow. Flow may not always be directly down the watershed slope if tillage runs across the slope.

After determining average velocity in figure 3-1, use equation 3-1 to estimate travel time for the shallow concentrated flow segment.

Open channels

Open channels are assumed to begin where surveyed cross section information has been obtained, where channels are visible on aerial photographs, or where blue lines (indicating streams) appear on United States Geological Survey (USGS) quadrangle sheets. Manning's equation or water surface profile information can be used to estimate average flow velocity. Average flow velocity is usually determined for bank-full elevation.

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TABLE 5.7.1

Approximate average velocities in ft/s of runoff flow for calculating time of concentration

Description of water course	Slope in percent 0–3	4–7	8–11	12–
Unconcentrated*				
Woodlands	0–1.5	1.5– 2.5	2.5– 3.25	3.25–
Pastures	0–2.5	2.5– 3.5	3.5– 4.25	4.25–
Cultivated	0–3.0	3.0– 4.5	4.5– 5.5	5.5–
Pavements	0–8.5	8.5–13.5	13.5–17	17–
Concentrated**				
Outlet channel—determine velocity by Manning's formula				
Natural channel not well defined	0–2	2–4	4–7	7–

*This condition usually occurs in the upper extremities of a watershed prior to the overland flows accumulating in a channel.

**These values vary with the channel size and other conditions. Where possible, more accurate determinations should be made for particular conditions by the Manning channel formula for velocity.

(*Source*: Drainage Manual, Texas Highway Department, Table VII, p. II-28, 1970.)

Because of the travel time to the watershed outlet, only part of the watershed may be contributing to surface water flow at any time t after precipitation begins. The growth of the contributing area may be visualized as in Fig. 5.7.1. If rainfall of constant intensity begins and continues indefinitely, then the area bounded by the dashed line labeled t_1 will contribute to streamflow at the watershed outlet after time t_1; likewise, the area bounded by the line labeled t_2 will contribute to

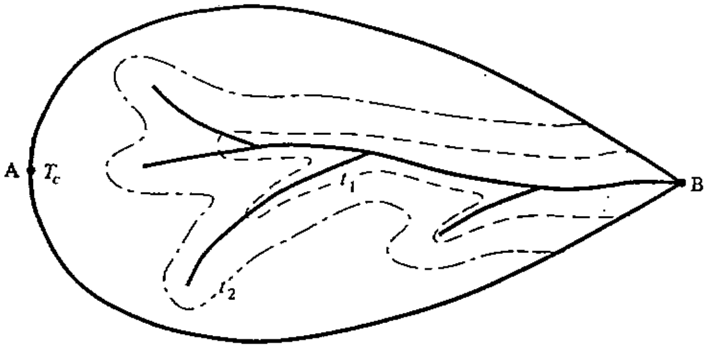

FIGURE 5.7.1

Isochrones at t_1 and t_2 define the area contributing to flow at the outlet for rainfall of durations t_1 and t_2. Time of concentration t_c is the time of flow from the farthest point in the watershed (A) to the outlet (B).

Selecting Rational Method Design Parameters

Time of Concentration. The use of appropriate values for time of concentration T_c is very important, although it is hard sometimes to judge what is the correct value. Local data collection efforts can be used to calibrate the T_c so that it works properly with the calibrated runoff coefficients. When this was done in Denver, the resulting peak flow estimates were found to be consistently within 20 percent of those obtained with calibrated distributed routing models.[66]

Equation (28.4.4) states that T_c is the sum of two flow times. The first is the initial time required for the surface runoff to reach the first swale, gutter, sewer, or channel. The second is the travel time in the conveyance elements.

$$T_c = t_i + t_t \qquad (28.4.4)$$

where T_c = time of concentration, min
t_i = initial inlet or sheet flow time, min
t_t = travel time in a conveyance element, min

Finding the initial time seems to create the greatest amount of confusion and conflict. It can be estimated by Eq. (28.4.5). This equation was developed for estimating the initial surface sheet flow time over short distances. This equation should not be used for distances larger than 200 to 300 ft under urban conditions. Surface flows beyond the initial sheet flow distance are likely to concentrate into either a swale, a gutter, or another type of conveyance element.

$$t_i = \frac{K_u\,[1.8\,(1.1 - C_5)\,L^{0.5}]}{S^{1/3}} \qquad (28.4.5)$$

where t_i = initial overland flow time, min
K_u = 1.0 for U.S. standard units (0.552 for SI units)
C_5 = runoff coefficient used for the 5-year storm
L = length of overland flow, ft (m)
S = average basin slope, %

Travel time is the time it takes the flow to travel through the various conveyance elements to the next inlet or design point. It is calculated by adding the time it takes the water to travel in each segment of the system from the point where the sheet flow (i.e., initial time t_i) enters a recognizable conveyance element.

Before the calculated value of T_c is used, it must be determined that the calculated value makes sense for the site. Figure 28.4.3 was developed by the U.S. Soil Conservation Service[82] and can be used as one of the checks to gauge if the final T_c makes sense. If the value of T_c calculated by any of the available equations differs significantly from the one calculated using the average flow velocity obtained from this figure, the calculations must be double-checked.

Often, limitations on the time of concentration are imposed by local governing agencies. For example, after a 10-year data-gathering effort, the maximum value of T_c for urban basins in Denver is limited by Eq. (28.4.6).[66] It is speculated that this is a reasonable limitation for urban basins having at least a 0.4 percent slope. Thus, if the calculated time of concentration exceeds this limiting value, the Eq. (28.4.6) value of T_c is used.

$$T_c = K_u\left(\frac{L}{180}\right) + 10 \qquad (28.4.6)$$

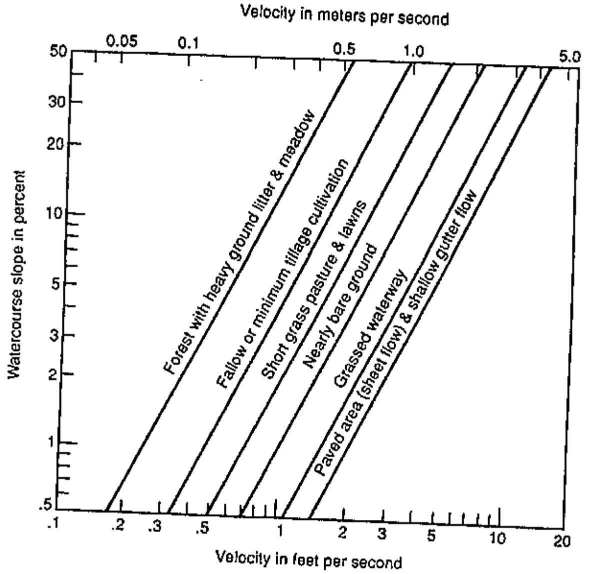

FIGURE 28.4.3 Estimate of average flow velocity for use with the rational formula. *(From Ref. 82.)*

where T_c = maximum time of concentration, min, for basins having a slope grea
or equal to 0.4 percent
L = maximum distance from inlet (design point) to watershed bounda
ft (m)
K_u = 1.0 for U.S. standard units (0.305 for SI units).

Runoff Coefficient. The runoff coefficient C varies with the type of surface area a the total depth and intensity of rainfall. Studies by Schaake and others[58,66] show that the runoff coefficient increases as the return period of the design storm increase Table 28.4.3 lists some of the values suggested in the Urban Storm Drainage Criter Manual for Denver.[66] These may or may not be appropriate for other localitie However, C for the smaller rainfall values in this table correspond well to the valu

TABLE 28.4.3 Runoff Coefficients Suggested for Denver, Colo., Area

Land use or surface type	2-h rainfall depth, in (mm)			
	1.2 (27)	1.7 (38)	2.0 (43)	3.1 (83)
Lawns, sandy soil	0.00	0.05	0.10	0.20
Lawns, clayey soil	0.05	0.15	0.25	0.50
Paved areas	0.87	0.88	0.90	0.93
Gravel streets	0.15	0.25	0.35	0.65
Roofs	0.80	0.85	0.90	0.93

Values in this table may be combined by area weighting. The coefficients may not be valid for watershed areas exceeding 160 to 200 acres (65 to 80 ha).
Source: After Ref. 66.

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equal t_c. Considering the rainfall of i in/h commencing at $t = 0$, at time $t = 1$ h, a area a acres contributes to flow at the outlet, and scaling up the volumetric identit that 1 in/h on 1 acre gives 1.008 or 1 ft^3/s, results in an outflow rate of $(Ci \cdot a)$. A $t = 2$ h, an area of $(a + b)$ acres contributes, and the outflow rate is $[Ci \cdot (a + b)$ ft^3/s. The area contributing increases with time until the time of concentration whe the whole area A contributes, and the outflow rate is (CiA) ft^3/s. This simplisti theoretical basis led to the name "rational method" compared with the prevailin arbitrary methods available when it was developed.

The basis enables assessment of the rational method as a description of the floo runoff process. The effects of rainfall and basin size are accounted for explicitly, an those of most other physical characteristics of the drainage basin are considere indirectly in the time of concentration and the runoff coefficient. The latter account for infiltration and other losses, though not in a physically realistic manner. Temporary storage and temporal and spatial variation of rainfall are neglected completely and the method is reasonably valid only where their effects are small. This may be the case on urban and small rural drainage basins. In practice, the runoff coefficient must take account of these neglected factors as well as infiltration and other losses, and the effects of antecedent wetness.

The simple theoretical basis also indicates why the critical duration of rainfall is assumed to be the time of concentration. For durations less than t_c, the whole area does not contribute. For durations greater than t_c, there is no increase in contributing area and the rainfall intensity of a given frequency decreases, and therefore a duration of t_c gives the highest peak flow. It is assumed that for durations less than t_c, the effect of the reduction in contributing area is greater than that of increased rainfall intensity. This is not the case if the first or last increments of travel time (see Fig. 9.4.1) give only small additions of contributing area or flow, and use of a shorter-duration rainfall may then be desirable.

Design Values. In application of the rational method, design values of time of concentration and runoff coefficient must be estimated. For urban areas, values of t_c are normally calculated as length divided by velocity determined by hydraulic formulas or tabulated values. For rural drainage basins, t_c is generally estimated by means of an empirical formula. Some of these are listed by Chow et al.[13] and French et al.[21] One of the formulas often used in the United States was derived by Kirpich based on data from six small agricultural drainage basins reported by Ramser.[68] The Kirpich formula is

$$t_c = 0.0078\, L^{0.77}\, S^{-0.385} \tag{9.4.2}$$

where t_c is in minutes, L is the length of channel from divide to outlet in feet, and S is the average channel slope in ft/ft. This formula has been found to give low values in Australia. Another formula that has been used in several countries was proposed by Bransby Williams.[7] A modified form with L in miles, A in mi^2, and S in ft/ft is

$$t_c = 21.3\, L\, A^{-0.1}\, S^{-0.2} \tag{9.4.3}$$

where the slope is that of a linear profile having the same area under it as the actual profile of the main stream. With units of L in km, A in km^2, and S in m/m, the coefficients in the above formulas are 3.97 and 14.6, respectively. The formula to be used in a particular region is a matter of judgment and is obviously a source of uncertainty. For routine design, it is important that a consistent procedure be used even in details such as the slope measure. The formula adopted for a region should be assessed to ensure that it gives reasonable average velocities, and if possible estimat

Subject BROADMOOR MDDP
By SWR
Checked By
Date 9/30/97
Date 11/11/97
Project No. 24389
Task No. 006
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Sheet 1 of 14

GIVEN

ESTIMATE CAPACITIES OF EXISTING CULVERTS WITHIN BROADMOOR RESORT COMMUNITY MDDP AREA.

GIVEN

- REVIEW OF EXISTING REPORTS
- 1" = 200' TOPOGRAPHIC MAP
- SITE RECONNAISSANCE AND FIELD MEASUREMENTS

SOLUTION

FOR PURPOSES OF THIS ANALYSIS AND GIVEN THE LOCATIONS OF THE CULVERTS IN STEEP CANYONS, IT WAS ASSUMED THAT CULVERTS WOULD BE INLET CONTROL (CULVERTS ASSUMED TO HAVE A SLOPE > 1%.

INLET CONTROL IS GIVEN BY

$$Q = C_d A \sqrt{2gh}$$

where Q = discharge (cfs)
C_d = coff. of discharge
A = flow area (ft^2)
h = head from ℄ (feet)
g = 32.2 ft^2/s

Subject

By

Checked By

Date

Date

Project No.

Task No.

File No.

Sheet 2 of 14

(200) FARTHING DRIVE 30" CMP $H \sim 5'$ $A = 4.91 ft^2 = \pi r^2$ ✓

$Q = C_d A \sqrt{2gh}$ $C_d = 0.70$ $Q = 0.70(4.91)\sqrt{2g(5)}$
$= 62 cfs$ ✓

(200) LANGDALE WAY 24" CMP $H = 6'$ $A = 3.14 ft^2$ ✓

$Q = 0.70(3.14)\sqrt{2g(6)} = 43 cfs$ ✓

(200) LANGDALE WAY 30" CMP $H = 7'$ $A = 4.91 ft^2$ ✓

$Q = 0.70(4.91)\sqrt{2g(7)} = 73 cfs$ ✓

(300) BROADMOOR BLUFFS DRIVE 60" CMP $H = 12\frac{1}{2}'$ $A = 19.63 ft^2$ ✓

$Q = 0.70(19.63)\sqrt{2g(12\frac{1}{2})} = 390 cfs$ ✓
for 416 cfs $H = 14'$

(400) BROADMOOR BLUFFS DRIVE 78" CMP $H = 12'$ $A = 33.18 ft^2$ ✓

$Q = 0.70(33.18)\sqrt{2g(12)} = 646 cfs$ ✓

(200) FARTHING DRIVE 108" CMP $H \sim 10'$ $A = 63.62 ft^2$ ✓

$Q = 0.70(63.62)\sqrt{2g(10)} =$ ~~455 cfs~~ $\approx$ 1130 cfs

(300) ELLSWORTH STREET 60" CMP $H \sim 11'$ $A \simeq 19.63 ft^2$ ✓

$Q = 0.70(19.63)\sqrt{2g(11)} = 366 cfs$ ✓
for 416 cfs $H = 14'$

STAR RANCH ROAD 18" CMP (GENERAL) $H \sim 2'$ $A = 1.77 ft^2$ ✓

$Q = 0.70(1.77)\sqrt{2g(2)} = 14 cfs$ ✓

24" HDPE (BASIN 500) $H \sim 3'$ $A = 3.14 ft^2$ ✓

$Q = 0.70(3.14)\sqrt{2g(3)} = 31 cfs$ ✓

Subject

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Date Date

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(300) ELLSWORTH STREET 48" RCP H ~ 8' $A = 12.57 ft^2$ ✓

$Q = 0.70(12.57)\sqrt{2g(8)} = 200$ cfs ✓

(500) BROADMOOR BLUFFS DR. 78" ORIFACE H ~ 12' A = 33.2 sq. ft. ✓

$Q = 0.70(33.2)\sqrt{2g(12)} = 646$ cfs ✓

90" RISER L = 23.5' H ~ 2.0'

$Q = CLH^{3/2} = 3.2(23.5)(2)^{3/2} = 213$ cfs ✓

TOTAL CAPACITY ~ 859 cfs ✓

Worksheet
Worksheet for Trapezoidal Channel

Project Description	
Project File	c:\fmw\broad.fm2
Worksheet	Exist. major drainage channel @ Boulders
Flow Element	Trapezoidal Channel
Method	Manning's Formula
Solve For	Discharge

✓

Input Data		
Mannings Coefficient	0.036	
Channel Slope	0.100000	ft/ft
Depth	2.50	ft
Left Side Slope	3.00	H : V
Right Side Slope	3.00	H : V
Bottom Width	8.00	ft

Results		
Discharge	699.77	ft^3/s
Flow Area	38.75	ft^2
Wetted Perimeter	23.81	ft
Top Width	23.00	ft
Critical Depth	3.95	ft
Critical Slope	0.014722	ft/ft
Velocity	18.06	ft/s
Velocity Head	5.07	ft
Specific Energy	7.57	ft
Froude Number	2.45	
Flow is supercritical.		

← HIGA OK

Worksheet
Worksheet for Trapezoidal Channel

✓

Project Description	
Project File	c:\fmw\broad.fm2
Worksheet	Fisher's Canyon estimate
Flow Element	Trapezoidal Channel
Method	Manning's Formula
Solve For	Channel Depth

Input Data		
Mannings Coefficient	0.040	
Channel Slope	0.100000	ft/ft
Left Side Slope	1.00	H : V
Right Side Slope	1.00	H : V
Bottom Width	4.00	ft
Discharge	560.00	ft³/s

Results		
Depth	3.82	ft
Flow Area	29.86	ft²
Wetted Perimeter	14.80	ft
Top Width	11.64	ft
Critical Depth	5.53	ft
Critical Slope	0.021879	ft/ft
Velocity	18.75	ft/s
Velocity Head	5.47	ft
Specific Energy	9.29	ft
Froude Number	2.06	
Flow is supercritical.		

⇒ RIP-RAP UP TO 5' DIA,
BOULDERS UP TO 6' DIA. (ASSUMED)

Subject

Project No.

By

Checked By

Task No.

File No.

Date

Date

Sheet 6 of 14

CAPACITY OF EXISTING 60" CMP @ BROADMOOR BLUFFS ⟹

$H \sim 14'$ $A = \pi r^2 = \pi(2.5)^2 = 19.63 \text{ ft}^2$ $h = 14 - 2.5' = 11.5'$

$$Q = C_d A \sqrt{2gh}$$

$$= 0.66(19.63)\sqrt{2g(11.5)} = 350 \text{ cfs}$$

FOR 416 cfs $C_d \sim 0.78$

for $H \sim 15'$ $Q = 0.66(19.63)\sqrt{2g(12.5)} = 368 \text{ cfs}$

CAPACITY OF EXISTING 78" CMP @ BROADMOOR BLUFFS ⟹

$H \sim 14'$ $A = \pi r^2 = \pi(3.25)^2 = 33.18 \text{ ft}^2$ $h = 14 - 3.25 = 10.75'$

$$Q = 0.66(33.18)\sqrt{2g(10.75)} = 576 \text{ cfs}$$

$$0.73(33.18)\sqrt{2g(10.75)} = 637 \text{ cfs}$$

$Q_{400} = 230 \text{ cfs}$ BULKED

$Q_{300} = 790 \text{ cfs}$ $Q_{TOTAL} = 1020 \text{ cfs}$

$Q_{CAPACITY} = 350 + 580 = 930 \text{ cfs}$

for $C = 0.73$ $Q_{CAPACITY} = \frac{0.73}{0.66}(930) = 1030 \text{ cfs}$

Woodward-Clyde

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Worksheet
Worksheet for Circular Channel

Project Description	
Project File	c:\fmw\broad.fm2
Worksheet	66" RCP at Boulders Broadmoor
Flow Element	Circular Channel
Method	Manning's Formula
Solve For	Discharge

Input Data		
Mannings Coefficient	0.013	
Channel Slope	0.100000	ft/ft
Depth	5.50	ft
Diameter	5.50	ft

Results		
Discharge	1061.86	ft³/s
Flow Area	23.76	ft²
Wetted Perimeter	17.28	ft
Top Width	0.00	ft
Critical Depth	5.49	ft
Percent Full	100.00	%
Critical Slope	0.097079	ft/ft
Velocity	44.69	ft/s
Velocity Head	31.04	ft
Specific Energy	FULL	ft
Froude Number	FULL	
Maximum Discharge	1142.25	ft³/s
Full Flow Capacity	1061.86	ft³/s
Full Flow Slope	0.100000	ft/ft

CHECK INLET CONTROL ⇒

✓ $h = \frac{5.5}{2} + \frac{11}{2} = 7.25'$

✓ $A = \pi r^2 = \pi (2.75)^2 = 23.76 \text{ ft}^2$

$Q = C_d A \sqrt{2gh}$

$= 0.70 (23.76) \sqrt{2g(7.25)}$

✓ $= 359$ cfs × 2 = ~~654~~ 720 cfs ~ ~~676~~ 720 cfs

OK

Subject ______

By　　　　Checked By

Date　　　　Date

Project No. ______

Task No. ______

File No. ______

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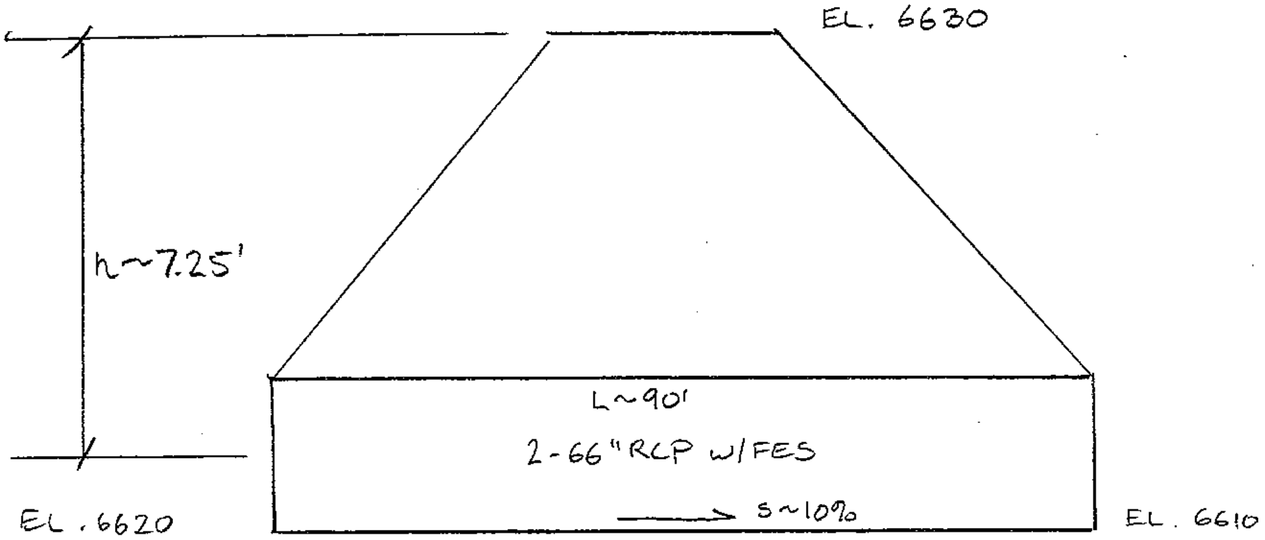

$Q = C_d A \sqrt{2gh}$

$A = 2 \times \pi r^2 = 2 \times \pi (2.75)^2$
$= 47.5\ ft^2$

$Q = 0.66(47.5)\sqrt{2g(7.25)}$
$= 677\ cfs$

for $Q = 750$ cfs　　$C_d = 0.73$　　ok

$h = 8.9'$

$\frac{HW}{D} = \frac{10}{5.5} = 1.82$

Subject
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Task No.
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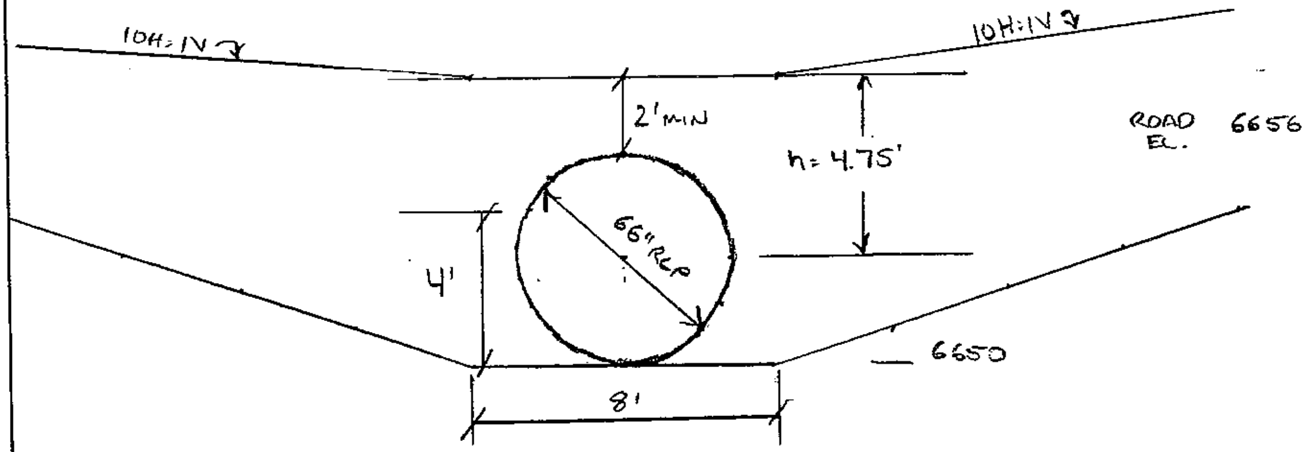
FOR DRIVEWAY OVERFLOW $h \sim 4'$

h	Q_{PIPE}	$Q_{O.F.}$	Q_{TOTAL}	H	A
4.75	274	0	274	0	
5.00	281	4	285	0.25	
5.50	295	28	323	0.75	
6.00	308	80	388	1.25	
6.50	321	165	486	1.75	44.63
7.00	333	288	621	2.25	68.63
7.50	345	351	696	2.75	97.63
8.00	356	664	1020	3.25	131.63

$Q_{DESIGN} \sim 750$ cfs



$Q_{PIPE} = C_d A \sqrt{2gh} = 0.66(23.76)\sqrt{2g}\sqrt{h} = 125.8\sqrt{h}$

$A = \pi r^2 = \pi(2.75)^2 = 23.76 ft^2$ $C = 0.66$

$Q_{OF} = CAH^{1/2}$ $A = 8 \times d + 10d^2$ $C = 2.8$

Subject ______ Project No. ______

By Checked By Task No. ______

File No. ______

Date Date Sheet 10 of 14

THEREFORE, DEPTH OVER DRIVEWAY IS APPROX 4' TO PASS 750 CFS.

CHANNEL SHOULD BE AT LEAST 10' DEEP AT CULVERT CROSSINGS

DEPTH OVER DRIVEWAY IS 1.3' TO PASS 400 CFS ok
(AVAILABLE FREEBOARD ~ 2')

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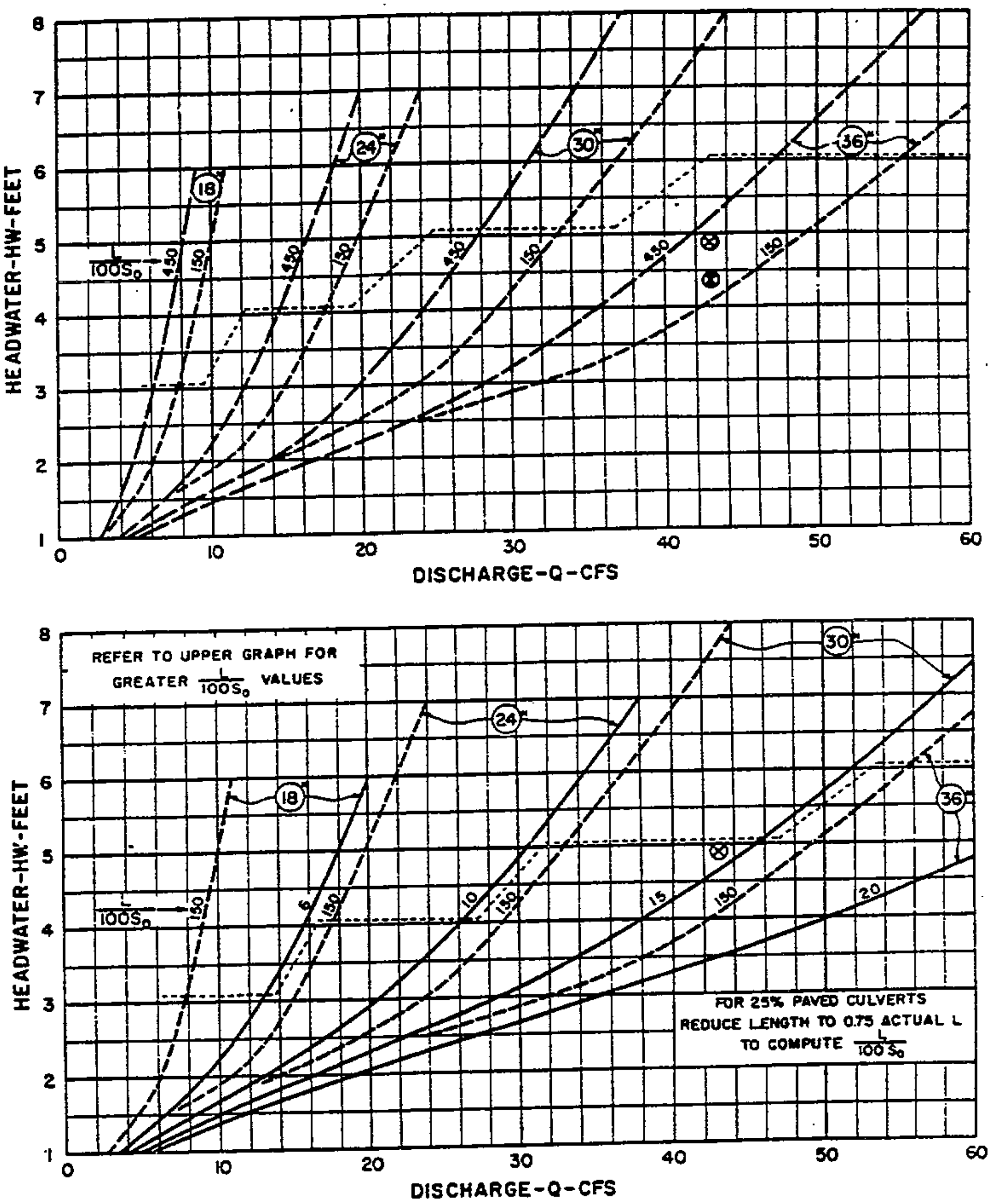

EXAMPLE

⊗ GIVEN:
43 CFS; AHW = 4.9 FT.
L = 72 FT.; S_o = 0.003

⊗ SELECT 36" UNPAVED
HW = 4.4 FT.

BUREAU OF PUBLIC ROADS JAN 1963

CULVERT CAPACITY
STANDARD
CIRCULAR CORR. METAL PIPE
HEADWALL ENTRANCE
18" TO 36" ○

HDR Infrastructure, Inc.
A Centerra Company

The City of Colorado Springs / El Paso County
Drainage Criteria Manual

Date
OCT. 1987

Figure
9 - 13

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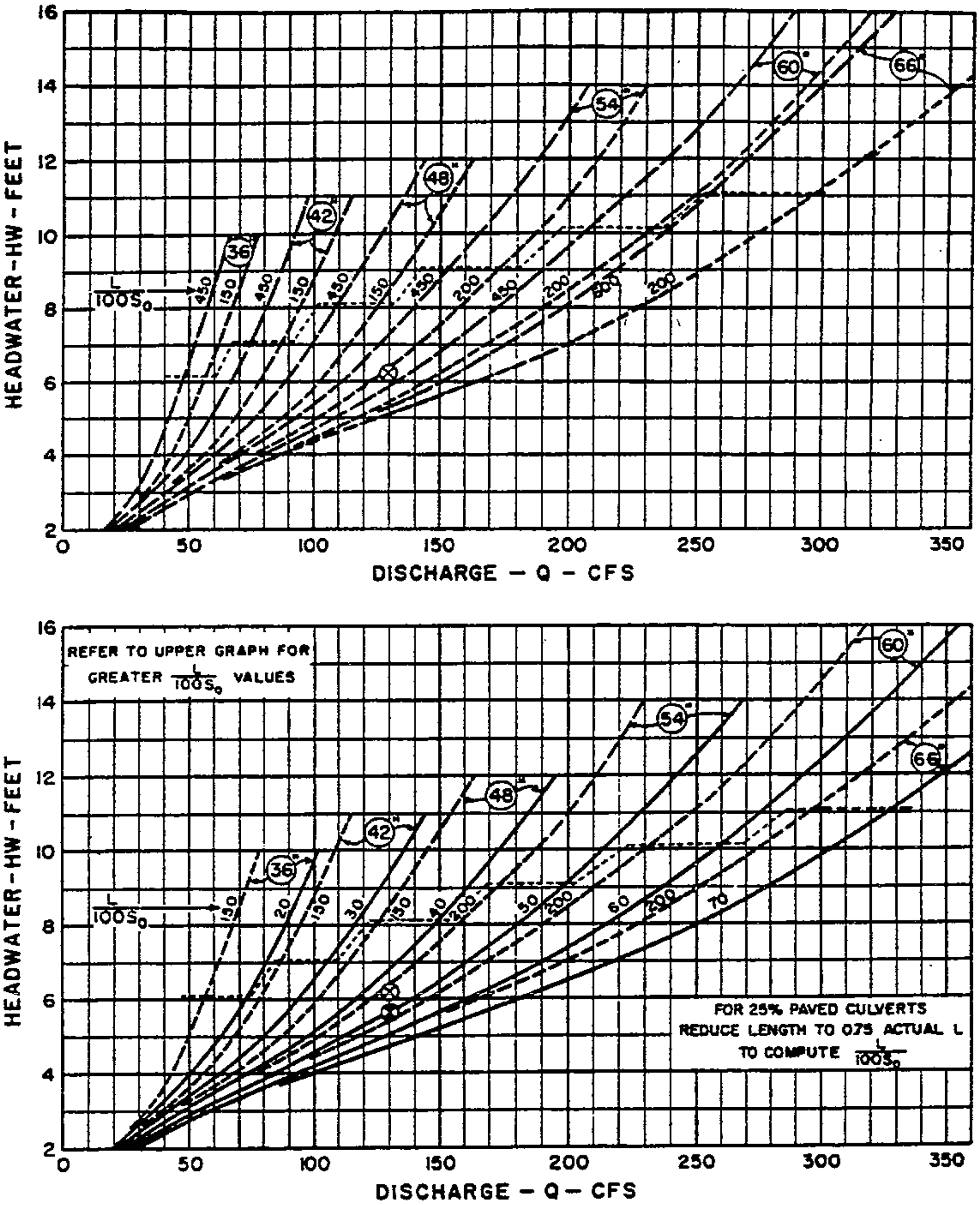

REFER TO UPPER GRAPH FOR GREATER $\frac{L}{100S_0}$ VALUES

FOR 25% PAVED CULVERTS REDUCE LENGTH TO 0.75 ACTUAL L TO COMPUTE $\frac{L}{100S_0}$

EXAMPLE

⊗ GIVEN:
130 CFS; AHW = 6.2 FT.
L = 120 FT.; S_0 = 0.025

⊗ SELECT 54" UNPAVED
HW = 5.6 FT.

BUREAU OF PUBLIC ROADS JAN. 1963

CULVERT CAPACITY
STANDARD
CIRCULAR CORR. METAL PIPE
HEADWALL ENTRANCE
36" TO 66" ○

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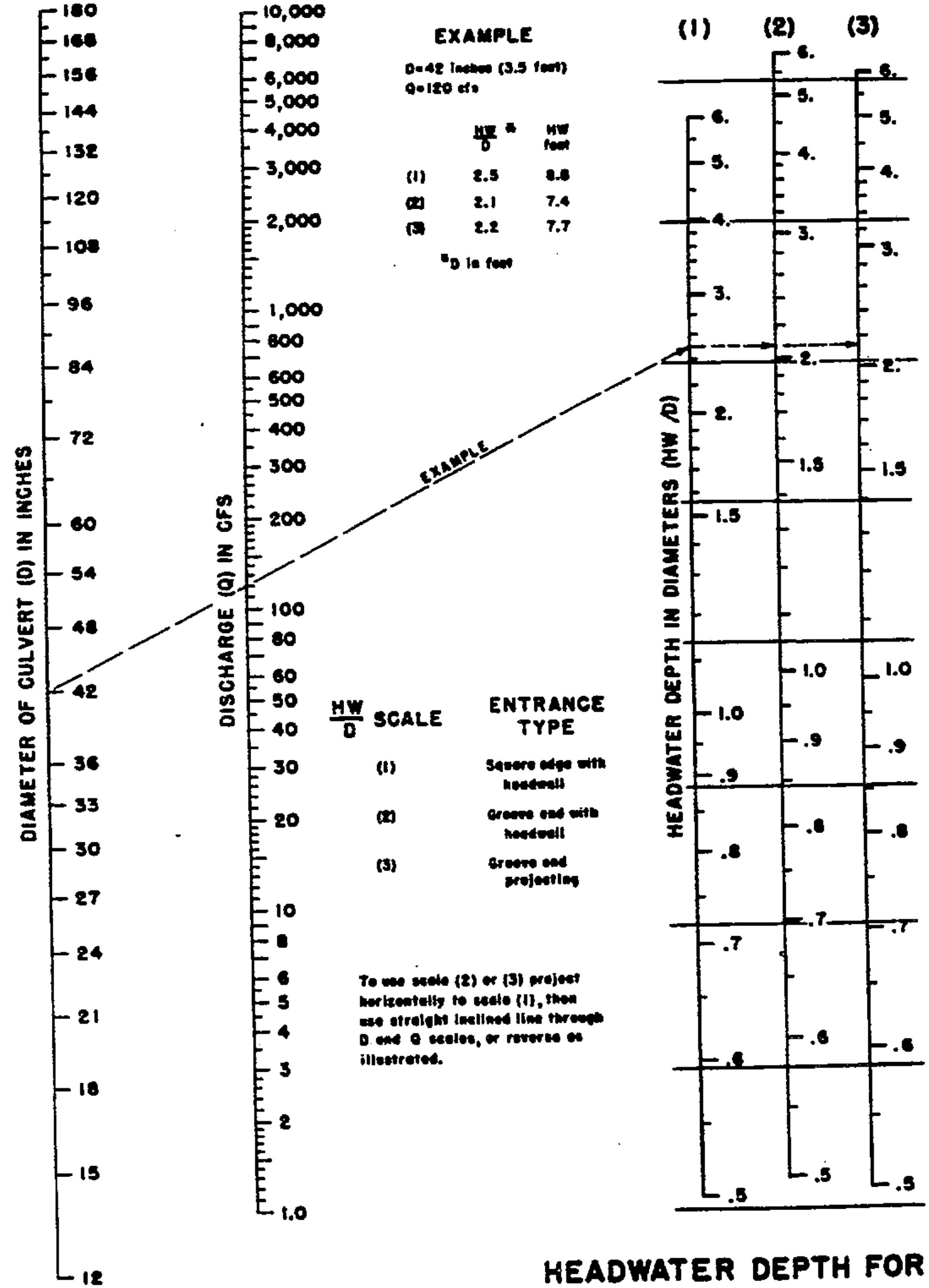


EXAMPLE

D=42 inches (3.5 feet)
Q=120 cfs

	$\frac{HW}{D}$ *	HW feet
(1)	2.5	8.8
(2)	2.1	7.4
(3)	2.2	7.7

*D in feet

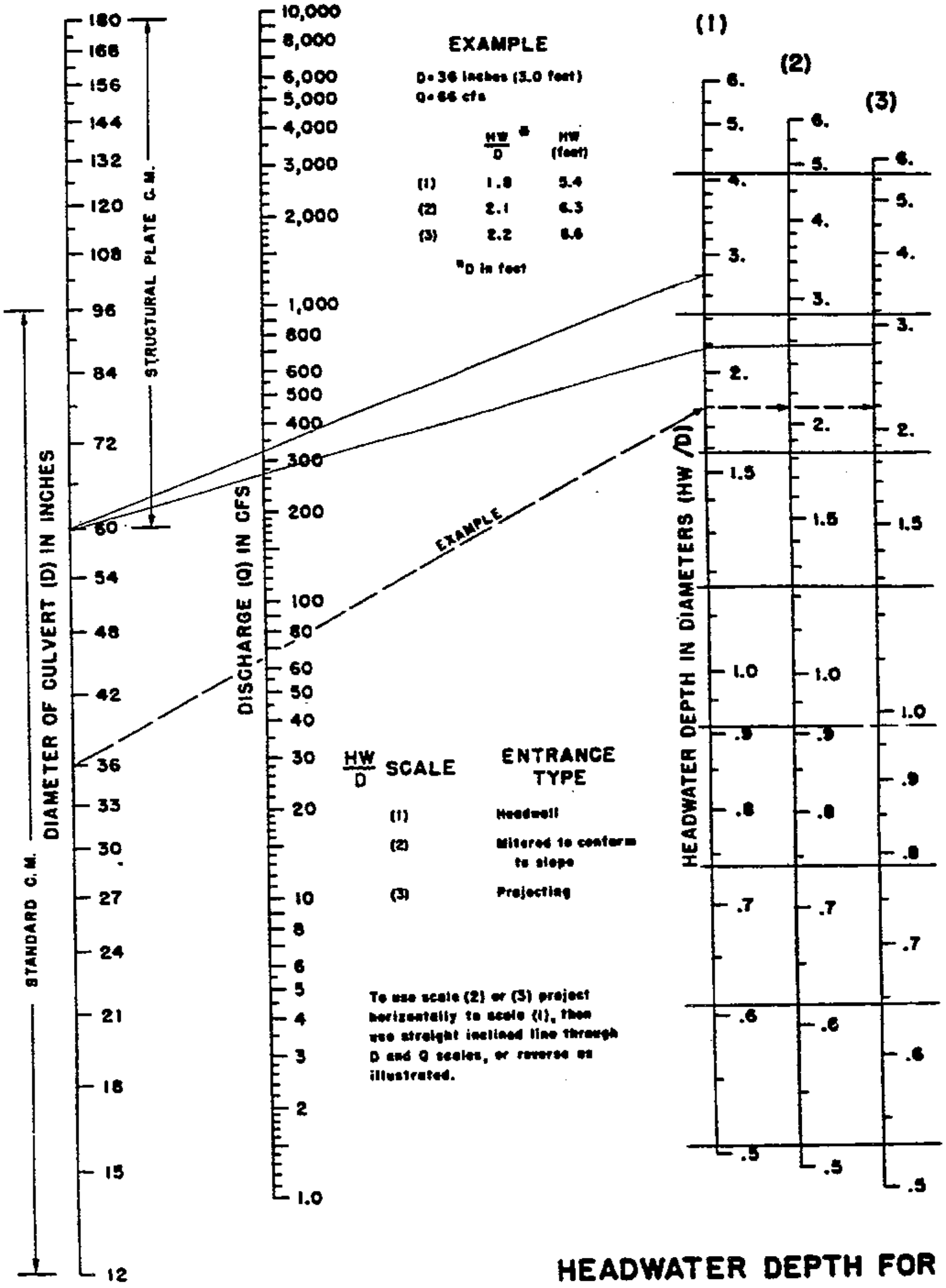
$\frac{HW}{D}$ SCALE	ENTRANCE TYPE
(1)	Square edge with headwall
(2)	Groove end with headwall
(3)	Groove end projecting

To use scale (2) or (3) project horizontally to scale (1), then use straight inclined line through D and Q scales, or reverse as illustrated.

HEADWATER DEPTH FOR CONCRETE PIPE CULVERTS WITH INLET CONTROL

HEADWATER SCALES 2&3
REVISED MAY 1964

BUREAU OF PUBLIC ROADS JAN. 1963



EXAMPLE

D=36 inches (3.0 feet)
Q=66 cfs

	$\frac{HW}{D}$ *	HW (feet)
(1)	1.8	5.4
(2)	2.1	6.3
(3)	2.2	6.6

*D in feet

$\frac{HW}{D}$ SCALE	ENTRANCE TYPE
(1)	Headwall
(2)	Mitered to conform to slope
(3)	Projecting

To use scale (2) or (3) project horizontally to scale (1), then use straight inclined line through D and Q scales, or reverse as illustrated.

HEADWATER DEPTH FOR C. M. PIPE CULVERTS WITH INLET CONTROL

BUREAU OF PUBLIC ROADS JAN. 1963

Figure
9-37

Subject BROADMOOR RESORT MDDP

By SWR

Date 10/28/97

Checked By

Date 11/11/97

Project No. 24389

Task No. 600

File No.

Sheet 1 of 16

OBJECTIVE

DETERMINE PREVIOUSLY ESTIMATED PEAK DISCHARGE VALUES FOR EXISTING DEVELOPMENTS DOWNSTREAM OF BROADMOOR RESORT DEVELOPMENT.

GIVEN

- VARIOUS REPORTS

SOLUTION

PEAK FLOW RATES AT VARIOUS DESIGN POINTS DETERMINED AND COMPARED TO FLOW RATES DETERMINED AS PART OF THIS MDDP.

Subject		Project No.
By	Checked By	Task No.
		File No.
Date	Date	Sheet 2 of 16

FROM FLO ENGINEERING (1995) ⇒

BASIN	AREA (SM)	Qp(100)	
3	0.023	25	✓
5/6	0.064	72	
7	0.014	15	
8	0.093	100	✓
9	0.085	94	
10/11	0.072	77	
12	0.494	560	✓

WCC	FLO	Qp (WCC)	Qp (FLO)	
DP8	10/11 & 12	598	637	✓
DP9	9	111	94	
DP7A	8 & 7	115	115	✓
DP56	5/6	70	72	
DP34	3+?	26	25	✓

checks ok

FROM NEIL RANCH MDDP ⇒

BASIN 100 CN ~ 73 Tc = 0.18 hours A = 0.158 sq.mi. ✓

200 CN ~ 77 Tc = 0.27 hours A = 0.601 sq.mi. ✓

Subject Broadmoor - Oliver Master Devel. Plans.

Project No.

Task No.

File No.

By MCB

Checked By

Date 10/8/97

Date

Sheet 3 of 16

1) Regional Detention Ponds @ - Broadmoor Bluffs

a) Regional Detention Pond No. 1

Q100 (historical) = 460 cfs. includes Fischer Canyon, 100yr, 24-hr.

Qoutlet = 430 cfs (both together)

d/s capacity = 590

b) Pond 2.

$Q_{outlet\ 100yr}$ = 1280 cfs.

$Q_{p\ HWY115}$ = 850 cfs.

Q_{HIST} = 1280 cfs.

Storage = 43 ac-ft.

<u>temp storage</u>

c) 120" structural plate culvert.

Storage vol. = 15,050 ft³ (.35 ac-ft)

omitted from model.

d) 90" culvert

Storage Capacity = 40,504 ft³ (.93 ac-ft).

Omitted from model.

e) 60" Culvert w/ 27" orifice

V = .56 ac-ft.

omitted from TR-20 model

Subject
Project No.
Task No.
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Sheet 4 of 16

C) Filings I and IA.

Fishers Canyon ⇒ 318 cfs (100-yr).

conveyed in 48" cmp 3.82% = S L = 300 ft
replace w/ 66" rcp (2x) at Jarmon St.

18" cmp ~~at Ellsworth~~? no - ~~[illegible]~~ 1 66" at w/S end driveway.

60" cmp at Broadmoor Bluffs? ✓ Historical

undeveloped values = ? 107 ? cfs
developed Qp = 211. ?

?

D) Broadmoor Bluff No. II & [illegible] Rock (Apr. 1, 89)
Qp at Jarmon + Stonebrook Ln ≅ 232, developed
≅ 453 historic

60" at Broadmoor Bluffs Dr. Qp = 495 cfs.
60" at Ellsworth Qp = 498 → 334 (by 60")
Qp historic = 452 cfs.

SUMMARY OF PREVIOUS FLOOD FLOW ESTIMATES
BROADMOOR

Drainage station Previous		5 Year	10 Year	100 Year	Crossing	WWC	5 Year	100 Year
Reference	Engineer							
H-4	Watts	64	-	203	Farthing Rd	-	-	-
H-6	Watts	286	-	812	Farthing Rd	DP 102	3	22
H-1..H-6	Watts	339	-	982	d/s Farthing Rd	-	-	-
I-1	Watts	28	-	92	Langdale Wy	DP 200	5	21
I-3	Watts	14	-	47	Stanwell St	-	-	-
4/12	Jeffries	-	67	182	Broadmoor Bluffs Drive	-	-	-
7/10	Jeffries	-	206	457	Broadmoor Bluffs Drive	DP 402	20	117 ?
Basin B	Jeffries	-	236	488 //	Broadmoor Bluffs Drive	DP 501	11	63 //
Basin A	Jeffries	-	388	705	Ravenglass Way	-	-	-

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7. Summary of Runoff:

As requested, the following is a summary of the 100-year and the 10-year design runoffs:

Hydrograph Point and Location:	Developed Runoff -cfs-		Historic Runoff -cfs-	Ultimat Design Runoff
	Inflow	Outflow		
100-year Runoffs:				
8 @ BM Bluffs Rd:	682	634	681	
@ East Bndry:	599	599	639	705
10 @ BM Bluffs Rd:	452	420	428	
@ East Bndry:	410	410	413	488
13 @ 78"CMP BM B Rd:	377	361	374	
@ 60"CMP BM B Rd:	160	160	152	
@ East Bndry:	554	554	564	690
10-Year Runoffs:				
8 @ BM Bluffs Rd:	432	418		
@ East Bndry:	388	388	402	N/A
10 @ BM Bluffs Rd:	236	215		
	209	209	212	N/A
13 @ 78"CMP BM B Rd:	206	206	205	
@ 60"CMP BM B Rd:	67	67	62	
@ East Bndry:	285	285	290	N/A

TABLE 1

NEAL RANCH PHASES 2 & 3
FILINGS 1 AND FARTHING DRIVE

Basin	Land Use	Pot. CN	Area (Ac)	T_c (Hr)	Q_{r5} (In)	Q_{r100} (In)	q_p (CSM/in)	Q_5 (cfs)	Q_{100} (cfs)
(1) H-2,3,&4	R&R	73	101	0.178	.37	1.17	1100	64	203
(1) H-1,5,&6	R&R	77	385.4	0.274	.50	1.42	950	286	812
(1) H-1 THROUGH 6	R&R	76	486.4	0.274	.47	1.36	950	339	982
(1) H-7	R&R	73	21.5	0.120	.37	1.17	1220	14.7	47.8
(1) H-1 THROUGH 8	R&R	76	570.3	0.354	.46	1.34	860	353	1027
(2) H-7-1	R&R	73	8.5	.17	.48	1.36	1100	7.0	19.9
(2) H-7-2	RES	78	5.2	.17	.48	1.36	1100	4.3	12.2
(2) H-7-3	RES	78	7.6	.17	.48	1.36	1100	6.3	17.8
(1) K-1	R&R	72	12.5	.12	.33	1.10	2330	7.8	26.3
(1) K-1&2	R&R	72	38.2	.21	.35	1.14	1040	21.6	71
(2) K-2-1	RES	75	8.9	.17	.43	1.30	1100	6.6	19.9
(2) K-2-2	RES	78	1.8	.17	.48	1.36	1100	1.5	4.2
(2) K-2-3	PAVED	98	1.0	.17	1.87	3.27	1100	3.2	5.6
(2) K-2-4	PAVED	98	0.8	.17	1.87	3.27	1100	2.6	4.5
(2) K-2-5	RES	75	6.5	.17	.43	1.30	1100	4.6	14.6
(2) K-2-6	RES	78	2.3	.17	.48	1.36	1100	1.9	5.4
(2) U-1	R&R	72	39.6	.17	.34	1.12	1100	23.1	76.2
(2) U-1-1	RES	78	3.5	.17	.48	1.36	1100	2.9	8.2
(2) U-1-2	RES	78	4.1	.17	.48	1.36	1100	3.4	9.6
(2) U-1-3	RES	78	0.6	.17	.48	1.36	1100	0.5	1.4
(2) U-1-4	RES	78	2.7	.17	.48	1.36	1100	2.2	6.3

(2) U-1-5	RES	78	2.1	.17	.48	1.36	1100	1.7	4.9
(2) U-1-6	RES	72	21.5	.17	.34	1.12	1100	12.6	41.4
(2) U-1-7	RES	78	3.4	.17	.48	1.36	1100	2.8	7.9
(2) U-1-8	RES	84	0.3	.17	.82	1.94	1100	0.4	1.0
(2) U-1-9	RES	78	1.2	.17	.48	1.36	1100	1.0	2.8
(2) U-1-4-A	RES	98	0.2	.17	1.87	3.27	1100	0.6	1.1
(2) V-1	R&R	72	5.5	.17	.34	1.12	1100	3.2	10.6
(2) V-1-1	RES	78	3.7	.17	.48	1.36	1100	3.1	8.6
(2) V-1-2	PAVED	98	0.5	.17	1.87	3.27	1100	1.6	2.8
(2) V-1-3	RES	78	1.3	.17	.48	1.36	1100	1.1	3.0

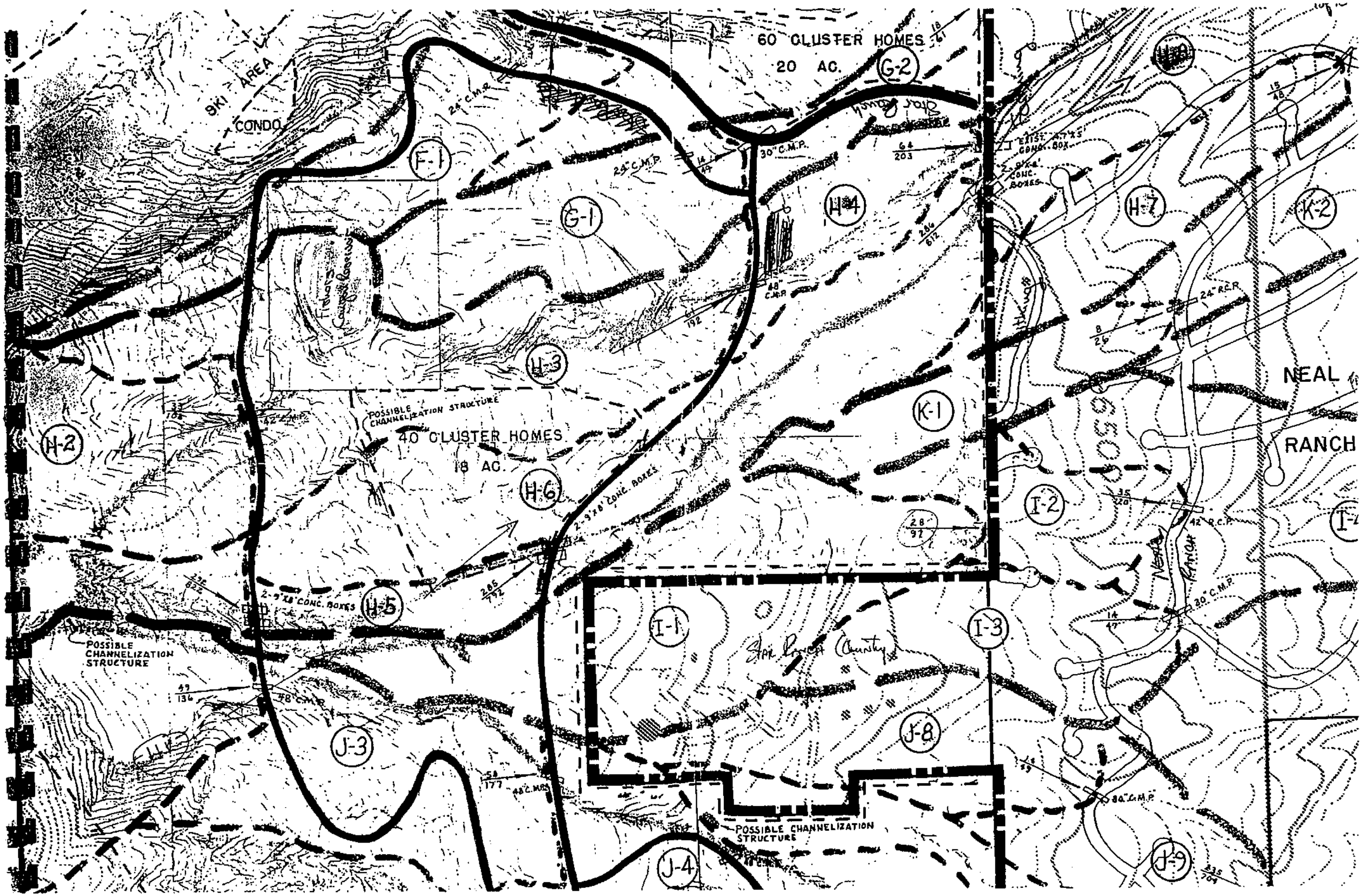
(1) Basin numbers and parameters from "Master Drainage Plan for Broadmoor South - Neal Ranch Drainage Basin," KLH Engineering, 1982.

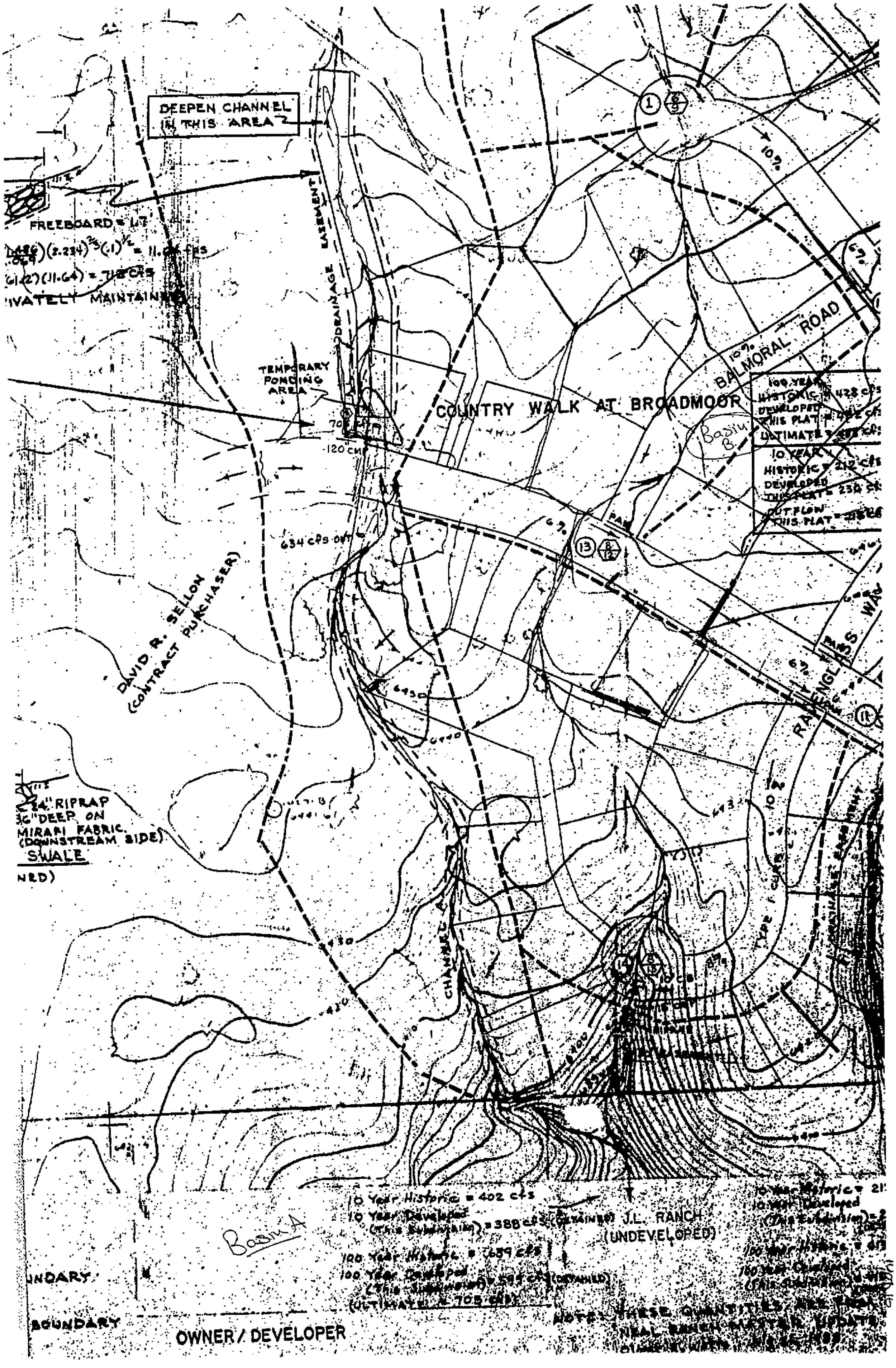
(2) Subbasin numbers and parameters from this report.

(3) Minimum time of concentration (T_c) used herein is 10 minutes (0.17) hr.

R&R = Range and Residential

RES = Residential


SKI AREA
CONDO
60 CLUSTER HOMES
20 AC.
18/61
G-2
Star Ranch
F-1
24" C.M.P.
24" C.M.P.
14/44
30" C.M.P.
64/203
EXIST. 4'x5' CONC. BOX
2-8'x4' CONC. BOXES
H-4
H-7
K-2
G-1
286/812
48" C.M.P.
192
24" R.C.P.
8/26
H-3
NEAL
RANCH
POSSIBLE CHANNELIZATION STRUCTURE
35/106
42" C.M.P.
40 CLUSTER HOMES
18 AC.
H-2
K-1
650
I-2
35/20
42" R.C.P.
I-4
H-6
2-9'x8' CONC. BOXES
28"/97
Neal Ranch
292/825
2-9'x8' CONC. BOXES
285/792
H-5
I-1
I-3
14/47
20" C.M.P.
POSSIBLE CHANNELIZATION STRUCTURE
Star Ranch County
49/134
48" C.M.P.
J-3
J-8
58/177
48" C.M.P.
16/59
84" C.M.P.
POSSIBLE CHANNELIZATION STRUCTURE
J-4
J-9


DEEPEN CHANNEL IN THIS AREA
FREEBOARD = 1.7
(1.486/.069)(2.234)^2/3(.1)^1/2 = 11.64 FPS
(61.27)(11.64) = 713 CFS
IVATELY MAINTAINED
DRAINAGE EASEMENT
TEMPORARY PONDING AREA
70" CMP
120" CMP
COUNTRY WALK AT BROADMOOR
BALMORAL ROAD
10%
6%
100 YEAR HISTORIC = 428 CFS
DEVELOPED THIS PLAT = 452 CFS
ULTIMATE =
10 YEAR HISTORIC = 212 CFS
DEVELOPED THIS PLAT = 230 CFS
OUTFLOW THIS PLAT =
Basin B.
634 CFS
DAVID R. SELLON (CONTRACT PURCHASER)
24" RIPRAP 36" DEEP ON MIRAFI FABRIC. (DOWNSTREAM SIDE)
SWALE
NED)
CHANNEL
RAMBLING WAY
6430
6440
6420
6410
6400
10 Year Historic = 402 cfs
10 Year Developed (This Subdivision) = 388 cfs (Detained)
100 Year Historic = 659 cfs
100 Year Developed (This Subdivision) = 597 cfs (Detained)
(ULTIMATE = 705 cfs)
J.L. RANCH (UNDEVELOPED)
Basin A
UNDARY
BOUNDARY
OWNER / DEVELOPER
10 Year Historic =
10 Year Developed (This Subdivision) =
100 Year Historic =
100 Year Developed (This Subdivision) =
NOTE: THESE QUANTITIES ARE TAKEN ... NEAL RANCH MASTER UPDATE

Kiowa copy
11 of 16

ONELL JEFFRIES
PROFESSIONAL ENGINEER
REGISTERED LAND SURVEYOR
SUBDIVISION LAYOUT AND DESIGN

704 S. 8th Street, Suite 209 A
Colorado Springs, Colorado 80905
(303) 634-4447

PRELIMINARY AND FINAL
DRAINAGE STUDY
GLEN OAKS AT BROADMOOR
COUNTRY WALK AT BROADMOOR
GLEN OAKS AT BROADMOOR FILING NO. 2

Prepared for:

DAVID R. SELLON & COMPANY
225 East Cheyenne Mountain Boulevard
Colorado Springs, Colorado 80906

October 17, 1988

TIMES OF CONCENTRATION

BASIN A
6,100 lin. ft. @ 3.3 fps = 1,848 seconds
2,500 " " @ 10.7 fps = 233 "
2,081 seconds = 34.7 min. = 0.578 hrs.

BASIN B
5,000 lin. ft. @ 3.3 fps = 1,515 seconds
2,500 " " @ 10.7 fps = 234 "
1,749 seconds = 29.1 min. = 0.486 hrs.

BASIN C
5,000 lin. ft. @ 3.3 fps = 1,515 seconds
3,000 lin. ft. @ 10.7 fps = 280 "
1,795 seconds = 29.9 min. = 0.499 hrs.

PEAK FLOWS

100 Year Storm, Precipation = 4.6 inches in 24 hours, Runoff = 1.971 inches

$D = 0.133\ TC$
$TP = .5\ D + 0.6\ TC$
$QP = \frac{484\ AQ}{TP}$

	Basin A	Basin B	Basin C
TC	0.578	0.486	0.499
D	0.0769	0.0646	0.0644
TP	0.3852	0.3239	0.3326
Square Miles	0.3672	0.3625	0.2641
QP	909 cfs	1,067 cfs	757 cfs

These developed peak flows are somewhat higher than those shown by Weiss Engineers, Inc. in the MASTER DRAINAGE STUDY OF NEAL RANCH, dated June 24, 1987. Their predicted quantities were:

	Without Channel Storage	With Channel Storage
Basin A	892 cfs	705 cfs
Basin B	630 cfs	488 cfs
Basin C	810 cfs	690 cfs

In order to check the peak quantities, we have therefore used another method of computing storm water runoff. Utilizing Figure 5-11d in the current Drainage Criteria Manual, "Peak Discharge in CSM per inch of runoff versus time of concentration", and the formula:

Peak Discharge = (CSM/in) (Sq. Miles) (Runoff)

Basin A = (540) (.3672) (1.971) = 391 cfs
Basin B = (580) (.3625) (1.971) = 414 cfs
Basin C = (575) (.2641) (1.971) = 299 cfs

The above quantities are based upon our previously discussed times of concentration. If we use the times of concentration shown in the Weiss Master Drainage Study, the peak discharges become:

Basin A = (760) (.3672) (1.971) = 550 cfs
Basin B = (800) (.3625) (1.971) = 572 cfs
Basin C = (760) (.2641) (1.971) = 396 cfs

The Neal Ranch Master Plan Update, July 21, 1988, Page 7, shows the following peak flows should be used for the ultimate design runoff:

Basin A	705 cfs	Broadmoor Bluffs Drive
Basin B	488 cfs	" " "
Basin C	690 cfs	East Boundary of the Filing

We will therefore size the subdivision facilities based upon the above quantities. Note that these peak flows are for fully developed conditions.

HISTORIC STORM WATER RUNOFF

The Neal Ranch Master Drainage Plan Update (Oliver Watts, July 21, 1988) shows that the installation of the culverts under Broadmoor Bluffs Drive will reduce the flows to the historic amount or less. The only exception is the 90" CMP at the low point in Broadmoor Bluffs Drive. At that point, a rather involved system of entrance pipes, 54", 96", and 78" will create enough ponding to maintain both the 10 year and 100 year flows below historic levels.

DRAINAGE EASEMENTS DOWNSTREAM

Although easements for drainage across the J L Ranch have already been obtained and recorded, easements will not be necessary because flows across these properties will be maintained at the historic levels.

SLOPES

BASIN A - 235 Acres - 0.3672 sq. miles

Length of Basin = 8,600 feet Total Drop in Basin = 2,900 feet
Drop of 630 feet in the lower 4,300 feet of length = slope of 15%
Drop of 2,300 feet in the upper 4,300 feet of length = slope of 55%

BASIN B - 232 Acres - 0.3625 sq. miles

Length of Basin = 7,500 feet Total Drop in Basin = 2,200 feet
Drop of 400 feet in the lower 3,750 feet of length = slope of 11 %
Drop of 1,800 feet in the upper 3,750 feet of length = slope of 50%

BASIN C - 169 acres - 0.2641 sq. miles

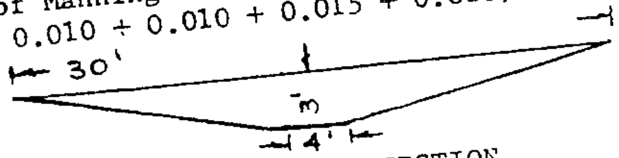
Length of Basin = 8,000 feet Total Drop in Basin = 2,500 feet
Drop of 500 feet in the lower 4,000 feet of length = slope of 12.5%
Drop of 2,000 feet in the upper 4,000 feet of length = slope of 50%

VELOCITIES

SCS Technical Release # 55, Page 3-2, indicates that on a 50% slope, with conditions mid-way between forest conditions and short grass, velocities would be 3.3 feet per second. These are obviously sheet flow conditions, not channelized.

For channelized conditions, we have assumed the following: (from Table 10-1, page 10-6 of manual)

Computation of Manning's n factor (from Table 10-1, page 10-6 of manual)
n = (0.024 + 0.010 + 0.010 + 0.015 + 0.010) (1.0) = 0.069



TYPICAL CHANNEL SECTION

Area = 51 sq. ft.
WP = 30.68 feet
R = 1.662
Slope = 12.5 %

$$V = \frac{1.486}{0.069} \times (1.662)^{2/3} \times (0.125)^{1/2}$$

$$V = 21.536 \times 1.403 \times 0.3536$$

V = 10.7 feet per second in channeled areas

FLOWS AND STORAGE AT BROADMOOR BLUFFS DRIVE

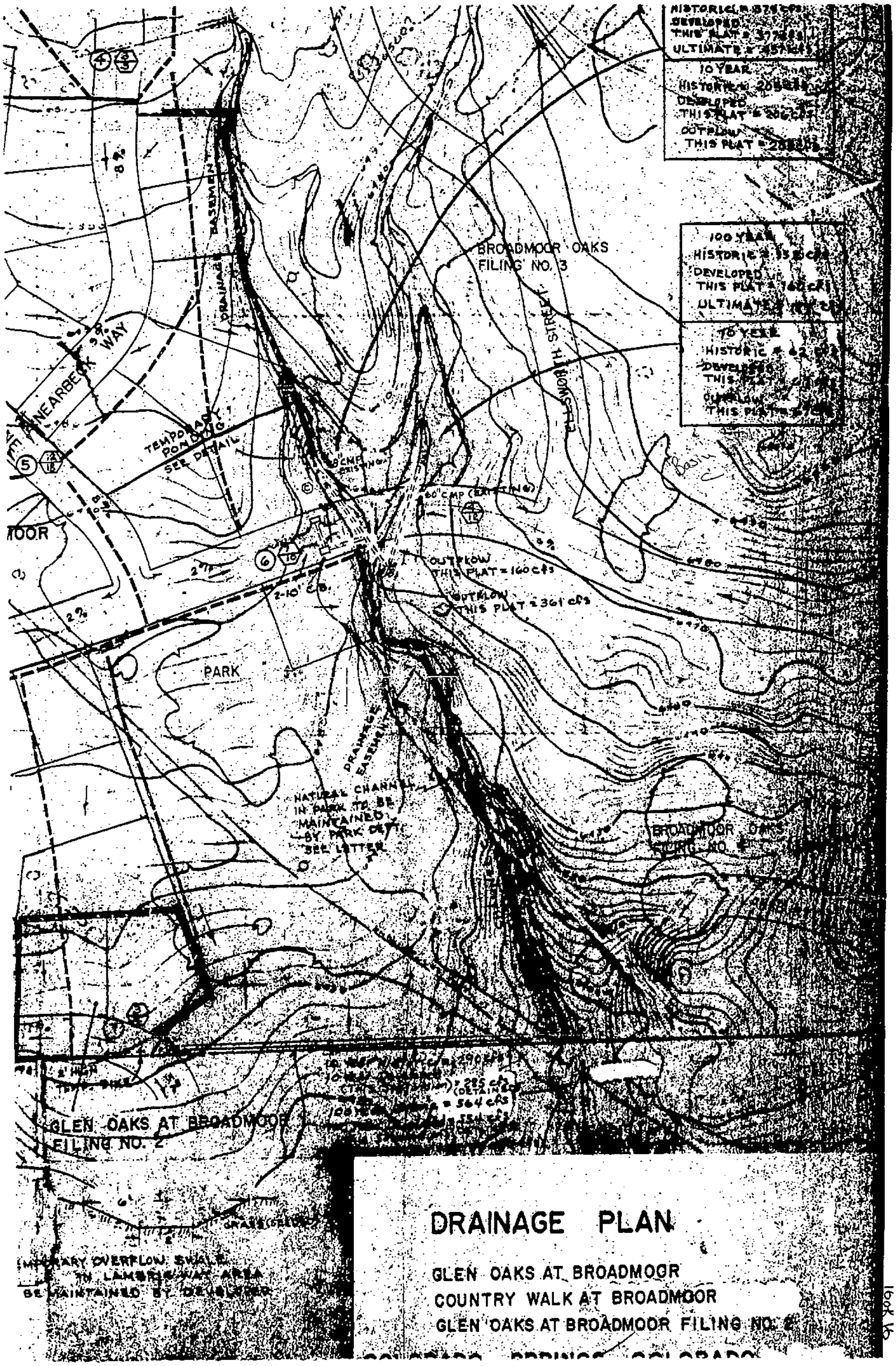
100 year Runoff Comparison

	Point # 8 Channel A	Point # 10 Channel B	Point # 13 Channel C 60" CMP	 78" CMP
Historic	681 cfs	428 cfs	152	374 cfs
Inflow this Plat	682 cfs	452 cfs	160	377 cfs
Outflow this Plat	659.8 cfs	420 cfs	160	361 cfs
Fully Developed	705 cfs	488 cfs	690 cfs (total)	
Storage Required (this plat)	12,669 cu. ft.	29,364 cu. ft.	3,594 c.f.-	13,664 c.f.
Invert	65.75 HW/D = 0.95	25.47 11.74 (depth)	49.71 HW/D=1.3	48.50 HW/D=1.4
HWL	75.25	37.21	56.21	57.60

NOTE: The above tabulation of storm water runoff and detention data has been compiled from three studies by O. E. Watts, Consulting Engineer. The studies were:

Neal Ranch Master Plan Update	May 5, 1988
	Revised	June 24, 1988
	Revised	July 21, 1988

Also refer to the attached letter of analysis dated October 4, 1988 from O. E. Watts.



DRAINAGE PLAN

GLEN OAKS AT BROADMOOR
COUNTRY WALK AT BROADMOOR
GLEN OAKS AT BROADMOOR FILING NO. 2
COLORADO SPRINGS, COLORADO

Book 16

Subject BROADMOOR RESORT MDDP
By SWR
Date 11/1/97

Checked By
Date

Project No. 24389
Task No. 600
File No.
Sheet 1 of 12

OBJECTIVE

CHECK RUNOFF RATES FROM "NEIL RANCH MASTER DRAINAGE STUDY"

GIVEN

- "NEIL RANCH MASTER DRAINAGE STUDY", (WEISS, 1987)
- "PRELIMINARY DRAINAGE PLAN AND REPORT, BROADMOOR BLUFFS No. 11 AND NEIL RANCH MASTER DRAINAGE PLAN UPDATE", (WATTS, 1989)
- FIGURE 88-1713-01 FROM WATTS, 1989.

SOLUTION

BASED ON NEW HYDROLOGIC ANALYSIS, PREVIOUSLY ESTIMATED FLOW RATES APPEAR TO BE VERY HIGH (COMPARED TO NEW FLOW RATES)

PREVIOUS ESTIMATES WERE MADE UTILIZING THE SCS GRAPHICAL METHOD AND THE RATIONAL METHOD.

A CHECK WAS MADE USING HEC-1 TO VERIFY CALCULATIONS IN THE ABOVE REFERENCED REPORTS. COMPUTATIONS WERE MADE UTILIZING THE SAME BASIN PARAMETERS USED IN THE PREVIOUS STUDIES

BASIN C-1 IS SIMILAR TO BASIN 500 AND BASIN D-1 IS SIMILAR TO BASIN 9@ DP9.

Subject
Project No.
Task No.
By
Checked By
File No.
Date
Date
Sheet 2 of 12

RESULTS ARE TABULATED BELOW ⟹

BASIN ID		D.A. (sq.mi.)		100-YR. Q (cfs)		
N.R.	WCC	N.R.	WCC	REPORT	HEC-1	WCC
C-1	500	0.288	0.178	616 qp= 2139	487 ~~392~~ ✓ Qp=292	141 ~~105~~
D-1	9	0.248	0.085	501 qp=2020	404 ~~323~~ ✓ Qp=1071	~~104~~ 91 ✓

?. (92/93)

RESULTS INDICATE THAT PREVIOUS ESTIMATES ARE TOO HIGH BASED ON DIFFERENT ANALYSIS METHODS AND OVERESTIMATION OF DRAINAGE AREA.

FROM USGS QUAD MAP, AREA ANALYZED AS PART OF THIS STUDY IS LESS THAN 1.5 sq.mi. TOTAL DRAINAGE AREA ANALYZED AS LISTED IN TABLE 1 IS 1.30 sq.mi.

3 of 12

RECEIVED
PUBLIC WORKS/ENGINEERING
COLORADO SPRINGS, COLO.

SEP 03 1987
AM 7 8 9 10 11 12 1 2 3 4 5 6 PM

MASTER DRAINAGE STUDY

FOR

(A portion of)
Southern

NEAL RANCH

4 of 12

Hydrograph Point	100 Year Flows (CFS) Historic	Developed	Required Detention
2	244	264	39,549
4	51	88	74,007
6	161	232	146,018
8	664	705	82,622
10	394	488	232,045
13	532	690	370,905

It is recommended that all drainageways through the Neal Ranch be left in their natural condition. As development takes place, building sites should be located outside the drainageways. As road culverts are installed, they should be designed with erosion protection on the downstream side to reduce the velocities to the capability of the natural channel.

We do not recommend that detention storage be designed on the site. The slopes are steep and would not allow efficient storage. We recommend that combined detention ponds be constructed on Gates Land Company and J L Ranch properties adjacent to Highway 115. The highway fill provides an interim detention pond prior to the permanent pond construction.

	MAJOR BASIN	SUB BASIN	AREA		BASIN		Tc	K	SOIL GROUP	DEV. TYPE	CURVE NO.		FLOW			q		
			Planim. Read. AC	MILE	LENGTH	HEIGHT							Q		qp			
											HIST	DEV	HIST	DEV		HIST	DEV	
⑨	C	1	184.11	0.28768	6000	2400	0.15		D B		74	78	0.47	0.85	900	173	220	5YR
													1.11	1.35		287	350	10 YR
													2.05	2.38		531	616	100
	C	2	46.83	0.073175	2700	240	0.14		B		55	66	0.10	0.37	920	7	25	5 YR
													0.28	0.69		19	46	10 YR
													0.79	1.46		53	98	100
⑩	C	3&2	230.94	0.360847	8700	2640	0.22		B D		70	76	0.50	0.76	790	143	217	5YR
													0.69	1.22		254	348	10 YR
													1.75	2.21		499	630	100

HYDROLOGIC COMPUTATION – BASIC DATA

PROJ: NEAL RANCH MASTER DRAINAGE

By: bgw

Date: 6-10-87

24 HOUR DURATION

WEISS CONSULTING ENGINEERS, INC.

5YR P: 2.6"

10YR P: 3.3"

100 YR P: 4.6"

Page 3 of Pages 4

5812

	MAJOR BASIN	SUB BASIN	AREA Planim. Read. AS	AREA MILE	BASIN LENGTH	BASIN HEIGHT	Tc	K	SOIL GROUP	DEV. TYPE	CURVE NO. HIST	CURVE NO. DEV	FLOW Q HIST	FLOW Q DEV	FLOW qp	HIST	DEV	
⑪	D	1	158.40	0.2475	7200	2680	0.18		D B		76	78	0.76	0.85	850	160	179	5YR
													1.22	1.35		257	284	10YR
													2.21	2.38		465	501	100
⑫	D	2	94.58	0.147785	5200	1470	0.16		D B		62	71	0.25	0.54	880	33	70	5YR
													0.52	0.94		68	122	10YR
													1.20	1.82		156	237	100
	D	3	64.28	0.100436	2800	235	0.15		B		55	66	0.10	0.37	900	9	33	5YR
													0.28	0.69		25	62	10YR
													0.79	1.48		71	132	100
	D	4	28.93	0.045196	2800	275	0.14		B		55	66	0.10	0.37	920	4	15	5YR
													0.28	0.69		12	29	10YR
													0.79	1.46		33	61	100
⑬	D	1,2,3,4	346.19	0.540942	10,000	2915	0.25		B D		67	73	0.40	0.63	760	164	259	5YR
													0.74	1.05		304	432	10YR
													1.53	1.97		629	810	100

HYDROLOGIC COMPUTATION – BASIC DATA

PROJ: NEAL RANCH MASTER DRAINAGE By: DJW Date: 6-10-87

24 HOUR DURATION

WEISS CONSULTING ENGINEERS, INC.

5YR P = 2.6"
10YR P = 3.3"
100 YR P = 4.6"

Page 4 of Pages 4

7of 12

OLIVER E. WATTS, PE-LS
CONSULTING ENGINEER, INC.
614 ELKTON DRIVE
COLORADO SPRINGS, COLORADO 80907
303-593-0173

June 16, 1987

Mr. G.J. Weiss, PE-LS
1815 N. Tejon Street
Colorado Springs, CO 80907

SUBJECT: Neal Ranch
Master Drainage Plan Computations

Dear Jerry

At your request, I have reviewed your basic hydrologic computations of the Neal Ranch, and I've computed the outfall hydrographs on the fully developed and historic basis, and the amount of detention required to hold the outfall to the historic peak level.

All of these computations are based on the current criteria of the 100-year, 24 hour storm, which will not change under the new, proposed criteria. The enclosed computations are provided, along with two of the basic runoff sheets, which have been used by me for all detention since I developed it for the 1977 Sand Creek basin study, and they have been approved for use by both the City and the County.

I have no problem with your basic hydrologic computations, although I had to extend the time of concentration to three decimal points for my purposes. Your peak runoff may be used for any of the individual basins. In computing the outfall hydrographs, however, it should be noted that the basins are very long and narrow, with extreme elevation differential. In these cases, it is best to combine hydrographs and provide hydrograph detention by channel storage, routing individual hydrographs downstream to combine them with the basic hydrograph of the downstream portions. In some basins, I have had to do this numerous times, but in this case, only two individual basins are required. The peak outfall runoff and required detention storage are as follows:

Hydrograph Point	Basins Used	Developed/Historic Peak Runoff - cfs	Detention - CF
2	A1, A2	264/244	39,549
4	A3, A4	88/ 51	74,007
6	B1, B2, B3	232/161	146,018
8	B4, B5	705/664	82,622
10	C1, C2	488/394	232,045
13	D1, D2, D3, D4	690/536	370,905

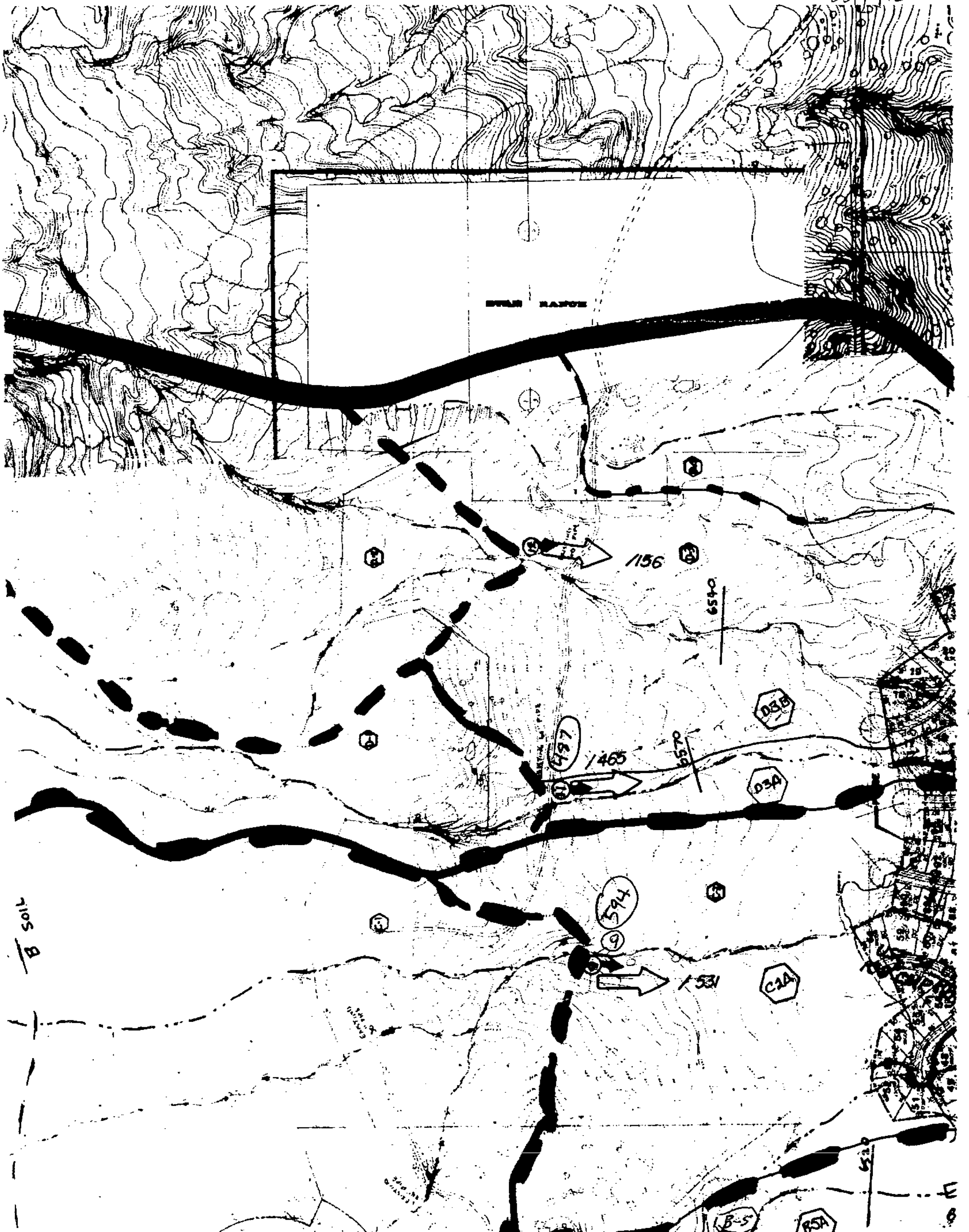
Please contact me if I may answer any questions.

Sincerely

Oliver E. Watts
Consulting Engineer

Encl

2of 1.2



9 of 12

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1*****************************************                                                   *********************************
 *                                       *                                                   *
 *   FLOOD HYDROGRAPH PACKAGE  (HEC-1)   *                                                   *    U.S. ARMY CORPS OF ENGINEER
 *              JUN 09 1992              *                                                   *    HYDROLOGIC ENGINEERING CENT
 *            VERSION 4.0.3E             *                                                   *          609 SECOND STREET
 *                                       *                                                   *       DAVIS, CALIFORNIA 95616
 *  RUN DATE  12/08/97  TIME  16:53:01   *                                                   *           (916) 551-1748
 *                                       *                                                   *
 *****************************************                                                   *********************************




                                                       X     X  XXXXXXX   XXXXX         X
                                                       X     X  X        X     X       XX
                                                       X     X  X        X              X
                                                       XXXXXXX  XXXX     X       XXXXX  X
                                                       X     X  X        X              X
                                                       X     X  X        X     X        X
                                                       X     X  XXXXXXX   XXXXX        XXX




          THIS PROGRAM REPLACES ALL PREVIOUS VERSIONS OF HEC-1 KNOWN AS HEC1 (JAN 73), HEC1GS, HEC1DB, AND HEC1KW.

          THE DEFINITIONS OF VARIABLES -RTIMP- AND -RTIOR- HAVE CHANGED FROM THOSE USED WITH THE 1973-STYLE INPUT STRUCTURE
          THE DEFINITION OF -AMSKK- ON RM-CARD WAS CHANGED WITH REVISIONS DATED 28 SEP 81. THIS IS THE FORTRAN77 VERSION
          NEW OPTIONS: DAMBREAK OUTFLOW SUBMERGENCE , SINGLE EVENT DAMAGE CALCULATION, DSS:WRITE STAGE FREQUENCY,
          DSS:READ TIME SERIES AT DESIRED CALCULATION INTERVAL   LOSS RATE:GREEN AND AMPT INFILTRATION
          KINEMATIC WAVE: NEW FINITE DIFFERENCE ALGORITHM



1                                                              HEC-1 INPUT                                                   PAGE  1

          LINE          ID.......1.......2.......3.......4.......5.......6.......7.......8.......9......10

             1          ID        CHECK OF RUNOFF FROM BASIN C1          100-YEAR, 24-HOUR STORM
             2          ID        NEIL RANCH MASTER DRAINAGE STUDY
             3          IT       1 11NOV97     1200     1000
             4          IN      30
             5          IO       5

             6          KK      C1
             7          KM        RUNOFF FROM D.A.
             8          BA    .288
             9          PB     4.6
            10          PC   0.000   0.005   0.010   0.015   0.020   0.028   0.035   0.043   0.050   0.058
            11          PC   0.065   0.073   0.080   0.090   0.100   0.110   0.120   0.130   0.140   0.160
            12          PC   0.180   0.205   0.235   0.285   0.665   0.735   0.775   0.800   0.820   0.835
            13          PC   0.850   0.865   0.880   0.890   0.900   0.910   0.920   0.928   0.935   0.943
            14          PC   0.950   0.956   0.963   0.969   0.975   0.981   0.988   0.994   1.000
            15          LS              78
            16          UD    0.15
            17          ZZ
1*****************************************                                                   *********************************
 *                                       *                                                   *
 *   FLOOD HYDROGRAPH PACKAGE  (HEC-1)   *                                                   *    U.S. ARMY CORPS OF ENGINEER
 *              JUN 09 1992              *                                                   *    HYDROLOGIC ENGINEERING CENT
 *            VERSION 4.0.3E             *                                                   *          609 SECOND STREET
 *                                       *                                                   *       DAVIS, CALIFORNIA 95616
 *  RUN DATE  12/08/97  TIME  16:53:01   *                                                   *           (916) 551-1748
 *                                       *                                                   *
 *****************************************                                                   *********************************





                                 CHECK OF RUNOFF FROM BASIN C1          100-YEAR, 24-HOUR STORM
                                 NEIL RANCH MASTER DRAINAGE STUDY

    5 IO          OUTPUT CONTROL VARIABLES
                        IPRNT          5  PRINT CONTROL
                        IPLOT          0  PLOT CONTROL
                        QSCAL         0.  HYDROGRAPH PLOT SCALE

      IT          HYDROGRAPH TIME DATA
                         NMIN          1  MINUTES IN COMPUTATION INTERVAL
                        IDATE    11NOV97  STARTING DATE
```

10 of 12

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                ITIME        1200  STARTING TIME
                   NQ        1000  NUMBER OF HYDROGRAPH ORDINATES
               NDDATE     12NOV97  ENDING DATE
               NDTIME        0439  ENDING TIME
                ICENT          19  CENTURY MARK

          COMPUTATION INTERVAL    0.02 HOURS
               TOTAL TIME BASE   16.65 HOURS

      ENGLISH UNITS
           DRAINAGE AREA          SQUARE MILES
           PRECIPITATION DEPTH    INCHES
           LENGTH, ELEVATION      FEET
           FLOW                   CUBIC FEET PER SECOND
           STORAGE VOLUME         ACRE-FEET
           SURFACE AREA           ACRES
           TEMPERATURE            DEGREES FAHRENHEIT
1
                                                          RUNOFF SUMMARY
                                                   FLOW IN CUBIC FEET PER SECOND
                                                TIME IN HOURS,  AREA IN SQUARE MILES

                                            PEAK    TIME OF        AVERAGE FLOW FOR MAXIMUM PERIOD         BASIN     MAXIMUM     TIME OF
             OPERATION        STATION       FLOW      PEAK                                                  AREA      STAGE     MAX STAGE
+                                                                6-HOUR       24-HOUR       72-HOUR

             HYDROGRAPH AT
+                                  C1        487.    12.03           71.           26.           26.        0.29


 *** NORMAL END OF HEC-1 ***
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1*****************************************                                                    *******************************
 *                                       *                                                    *
 *   FLOOD HYDROGRAPH PACKAGE  (HEC-1)   *                                                    *    U.S. ARMY CORPS OF ENGINEER
 *            JUN 09 1992                *                                                    *    HYDROLOGIC ENGINEERING CENT
 *          VERSION 4.0.3E               *                                                    *          609 SECOND STREET
 *                                       *                                                    *       DAVIS, CALIFORNIA 95616
 *  RUN DATE  12/08/97  TIME  16:53:29   *                                                    *           (916) 551-1748
 *                                       *                                                    *
 *****************************************                                                    *******************************




                                         X     X  XXXXXXX   XXXXX          X
                                         X     X  X        X     X        XX
                                         X     X  X        X               X
                                         XXXXXXX  XXXX     X       XXXXX   X
                                         X     X  X        X               X
                                         X     X  X        X     X         X
                                         X     X  XXXXXXX   XXXXX         XXX




                 THIS PROGRAM REPLACES ALL PREVIOUS VERSIONS OF HEC-1 KNOWN AS HEC1 (JAN 73), HEC1GS, HEC1DB, AND HEC1KW.

                 THE DEFINITIONS OF VARIABLES -RTIMP- AND -RTIOR- HAVE CHANGED FROM THOSE USED WITH THE 1973-STYLE INPUT STRUCTURE
                 THE DEFINITION OF -AMSKK- ON RM-CARD WAS CHANGED WITH REVISIONS DATED 28 SEP 81. THIS IS THE FORTRAN77 VERSION
                 NEW OPTIONS: DAMBREAK OUTFLOW SUBMERGENCE , SINGLE EVENT DAMAGE CALCULATION, DSS:WRITE STAGE FREQUENCY,
                 DSS:READ TIME SERIES AT DESIRED CALCULATION INTERVAL   LOSS RATE:GREEN AND AMPT INFILTRATION
                 KINEMATIC WAVE: NEW FINITE DIFFERENCE ALGORITHM


1                                                        HEC-1 INPUT                                                    PAGE  1

         LINE           ID.......1.......2.......3.......4.......5.......6.......7.......8.......9......10

           1            ID        CHECK OF RUNOFF FROM BASIN D1          100-YEAR, 24-HOUR STORM
           2            ID        NEIL RANCH MASTER DRAINAGE STUDY
           3            IT       1 11NOV97    1200     1000
           4            IN      30
           5            IO       5

           6            KK      D1
           7            KM        RUNOFF FROM D.A.
           8            BA    .247
           9            PB     4.6
          10            PC   0.000   0.005   0.010   0.015   0.020   0.028   0.035   0.043   0.050   0.058
          11            PC   0.065   0.073   0.080   0.090   0.100   0.110   0.120   0.130   0.140   0.160
          12            PC   0.180   0.205   0.235   0.285   0.665   0.735   0.775   0.800   0.820   0.835
          13            PC   0.850   0.865   0.880   0.890   0.900   0.910   0.920   0.928   0.935   0.943
          14            PC   0.950   0.956   0.963   0.969   0.975   0.981   0.988   0.994   1.000
          15            LS              78
          16            UD    0.18
          17            ZZ
1*****************************************                                                    *******************************
 *                                       *                                                    *
 *   FLOOD HYDROGRAPH PACKAGE  (HEC-1)   *                                                    *    U.S. ARMY CORPS OF ENGINEER
 *            JUN 09 1992                *                                                    *    HYDROLOGIC ENGINEERING CENT
 *          VERSION 4.0.3E               *                                                    *          609 SECOND STREET
 *                                       *                                                    *       DAVIS, CALIFORNIA 95616
 *  RUN DATE  12/08/97  TIME  16:53:29   *                                                    *           (916) 551-1748
 *                                       *                                                    *
 *****************************************                                                    *******************************




                                  CHECK OF RUNOFF FROM BASIN D1          100-YEAR, 24-HOUR STORM
                                  NEIL RANCH MASTER DRAINAGE STUDY

    5 IO          OUTPUT CONTROL VARIABLES
                        IPRNT           5  PRINT CONTROL
                        IPLOT           0  PLOT CONTROL
                        QSCAL          0.  HYDROGRAPH PLOT SCALE

      IT          HYDROGRAPH TIME DATA
                         NMIN           1  MINUTES IN COMPUTATION INTERVAL
                        IDATE     11NOV97  STARTING DATE
```

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```
                  ITIME        1200  STARTING TIME
                     NQ        1000  NUMBER OF HYDROGRAPH ORDINATES
                 NDDATE     12NOV97  ENDING DATE
                 NDTIME        0439  ENDING TIME
                  ICENT          19  CENTURY MARK

             COMPUTATION INTERVAL    0.02 HOURS
                  TOTAL TIME BASE   16.65 HOURS

         ENGLISH UNITS
              DRAINAGE AREA          SQUARE MILES
              PRECIPITATION DEPTH    INCHES
              LENGTH, ELEVATION      FEET
              FLOW                   CUBIC FEET PER SECOND
              STORAGE VOLUME         ACRE-FEET
              SURFACE AREA           ACRES
              TEMPERATURE            DEGREES FAHRENHEIT
1
                                                                  RUNOFF SUMMARY
                                                          FLOW IN CUBIC FEET PER SECOND
                                                       TIME IN HOURS,  AREA IN SQUARE MILES

                                               PEAK    TIME OF     AVERAGE FLOW FOR MAXIMUM PERIOD        BASIN     MAXIMUM     TIME OF
           OPERATION        STATION            FLOW      PEAK                                              AREA      STAGE     MAX STAGE
+                                                                  6-HOUR       24-HOUR      72-HOUR

           HYDROGRAPH AT
+                                D1            404.    12.05          61.          23.          23.       0.25


 *** NORMAL END OF HEC-1 ***
```

Subject BROADMOOR SOUTH MDDP

Project No. 24389

By SWR

Checked By

Task No. 600

File No.

Date 12/1/97

Date

Sheet 1 of 2

OBJECTIVE

DETERMINE RUNOFF VOLUMES FOR WATERSHEDS FOR THE 100-YEAR FREQUENCY EVENT.

GIVEN

- SCS CURVE NUMBERS & % IMP AREA
- $DRO = \frac{(P - 0.2S)^2}{P + 0.8S}$ $\quad S = \frac{1000}{CN} - 10$

$P_{100} = 3.1''$

SOLUTION

SPREADSHEET SET-UP TO CALC. VOLUME BASED ON SCS EQ.

RUNOFF FROM IMPERVIOUS AREAS EQUALS 100% OF PRECIP. DEPTH

2of2

TABLE 1
SUMMARY OF HYDROLOGIC PARAMETERS

BASIN ID	AREA (mi^2)	CN Ext.	CN Dev.	t_t (hours)	t_c (hours)	C	I ("/hour)	Q (cfs)	q (cfs/sm)	Q for q=1400	Q by SCS	% Q	% Impervious	100-yr V Imp.	S Dev.	100-yr V Dev.	S Ext.	100-yr V Ext.
34	0.023	74	74	0.125	0.208	0.35	6.7	313	13594	32.2			7	0.27	3.51	1.38	3.51	1.38
5	0.042	74	74	0.131	0.218	0.35	6.5	318	7569	58.8			7	0.25	3.51	2.28	3.51	2.28
6	0.022	74	74	0.131	0.218	0.35	6.5	318	14450	30.8			7	0.16	3.51	1.22	3.51	1.22
7	0.014	74	74	0.107	0.178	0.35	6.8	272	19403	19.6			7	0.65	3.51	1.32	3.51	1.32
8-1	0.056	74	74	0.133	0.222	0.35	6.4	318	5675	78.4			7	0.19	3.51	2.89	3.51	2.89
8-2	0.016	75	75	0.086	0.143	0.35	7.2	231	14448	22.4			7	0.24	3.33	1.06	3.33	1.06
8-3	0.021	74	74	0.202	0.337	0.35	5	377	17958	29.4			7	0.98	3.51	2.00	3.51	2.00
9	0.085	74	74	0.125	0.208	0.35	6.7	313	3678	119			4	0.23	3.51	4.46	3.51	4.46
1011-1	0.035	74	74	0.160	0.267	0.35	5.8	346	9899	49			7	0.43	3.51	2.12	3.51	2.12
1011-2	0.037	74	74	0.160	0.267	0.35	5.8	346	9364	51.8			7	1.03	3.51	2.81	3.51	2.81
12-1	0.089	76	76	0.126	0.210	0.35	6.4	301	3383	124.6			6	0.28	3.16	5.11	3.16	5.11
12-2	0.028	76	76	0.113	0.188	0.35	6.8	287	10245	39.2			6	0.27	3.16	1.79	3.16	1.79
12-3	0.027	76	76	0.145	0.242	0.35	5.9	319	11829	37.8			6	0.39	3.16	1.84	3.16	1.84
12-4	0.038	74	74	0.110	0.183	0.35	6.8	279	7349	53.2			6	0.80	3.51	2.66	3.51	2.66
12-5	0.081	76	76	0.154	0.257	0.35	5.7	328	4048	113.4			10	1.01	3.16	5.22	3.16	5.22
12-6	0.061	76	76	0.129	0.215	0.35	6.5	313	5132	85.4			10	0.26	3.16	3.44	3.16	3.44
12-7	0.016	75	75	0.134	0.223	0.35	6.1	305	19073	22.4			5	0.19	3.33	1.02	3.33	1.02
12-8	0.023	75	75	0.077	0.128	0.35	7.4	213	9249	32.2			5	0.17	3.33	1.37	3.33	1.37
12-9	0.021	75	75	0.112	0.187	0.35	6.8	284	13540	29.4			4	0.46	3.33	1.56	3.33	1.56
12-10	0.069	75	75	0.170	0.283	0.35	5.5	349	5059	96.6			5	0.34	3.33	3.93	3.33	3.93
12-11	0.041	74	74	0.073	0.122	0.35	7.5	204	4985	57.4			10	0.79	3.51	2.71	3.51	2.71
100A	0.048	58	66	0.138	0.230	0.45	6	397	8280	67.2	28	42	4	0.15	5.15	1.60	7.24	0.90
100B	0.022	58	66	0.132	0.220	0.45	6.4	406	18432	30.8	13	42	4	0.23	5.15	0.90	7.24	0.58
100C	0.035	58	72	0:150	0.250	0.45	5.8	418	11931	49	31	63	4	0.23	3.89	1.79	7.24	0.78
200A	0.035	58	70	0.144	0.240	0.45	5.9	408	11652	49	27	55	4	0.11	4.29	1.49	7.24	0.66
200B	0.017	58	72	0.144	0.240	0.45	5.9	408	23989	23.8	15	63	4	0.34	3.89	1.09	7.24	0.60
200C	0.051	58	72	0.144	0.240	0.45	5.9	408	7996	71.4	45	63	4	0.32	3.89	2.59	7.24	1.13
300A	0.049	58	65	0.162	0.270	0.45	5.6	435	8887	68.6	25	36	4	0.17	5.38	1.56	7.24	0.94
300B	0.026	58	68	0.126	0.210	0.45	6.4	387	14887	36.4	18	49	4	0.40	4.71	1.30	7.24	0.81
300C	0.06	58	72	0.150	0.250	0.45	5.8	418	6960	84	53	63	4	0.13	3.89	2.80	7.24	1.07
400A	0.02	58	72	0.210	0.350	0.45	5	504	25200	28	16	57	4	0.07	3.89	0.96	7.24	0.38
400B	0.01	58	72	0.210	0.350	0.45	5	504	50400	14	8	57	4	0.24	3.89	0.68	7.24	0.40
500A	0.036	58	72	0.162	0.270	0.45	5.6	435	12096	50.4	31	62	4	0.06	3.89	1.66	7.24	0.62
500B	0.009	58	72	0.108	0.180	0.45	6.9	358	39744	12.6	9	71	4	0.10	3.89	0.50	7.24	0.24
500C	0.015	58	72	0.108	0.180	0.45	6.9	358	23846	21	15	71	4	0.00	3.89	0.67	7.24	0.24

TOTAL VOLUME INCREASE ⟹

BASIN	500	1.9 AC-FT
	400	0.9 AC-FT
	300	2.9 AC-FT
	200	0.5 AC-FT
	100	2.0 AC-FT

Subject BROADMOOR SOUTH MDDP

Project No. 24389

By SWR

Checked By

Task No. 600

File No.

Date 12/3/97

Date

Sheet 1 of 7

OBJECTIVE

DETERMINE FLOW RATES FOR WATERSHEDS BY UTILIZING RATIONAL EQUATION

GIVEN

- BASIN AREAS, CN and t_t
- "DRAINAGE CRITERIA MANUAL"

SOLUTION

BASED ON RATIONAL EQUATION, PEAK UNIT DISCHARGE RATES ARE MUCH LARGER THAN THOSE EXPECTED FOR THE PROPOSED DEVELOPMENT

$C = 0.35$ NATURAL WATERSHED

$C = 0.45$ DEVELOPED CONDITIONS

t_c ESTIMATED FROM LAG TIME.

EQUATION SET-UP IN SPREAD SHEET. ⟹ SEE ATTACHED

Q FOR 1400 cfs/sq.mi. CHECKED AGAINST SCS METHOD, AVG. DIFFERENCE IS APPROX 50%

i. BASED ON FIGURE 5-1

TABLE 1
SUMMARY OF HYDROLOGIC PARAMETERS

BASIN ID	AREA (mi^2)	CURVE NUMBER	t_l (hours)	t_c (hours)	C	i ("/hour)	Q (cfs)	q (cfs/sm)	Q for q=1400	Q by SCS	% Q
34	0.023	74	0.125	0.208	0.35	6.7	313	13594	32.2		
5	0.042	74	0.131	0.218	0.35	6.5	318	7569	58.8		
6	0.022	74	0.131	0.218	0.35	6.5	318	14450	30.8		
7	0.012	74	0.107	0.178	0.35	6.8	272	22636	16.8		
8-1	0.056	74	0.133	0.222	0.35	6.4	318	5675	78.4		
8-2	0.016	75	0.086	0.143	0.35	7.2	231	14448	22.4		
8-3	0.021	74	0.202	0.337	0.35	5	377	17956	29.4		
9	0.085	74	0.125	0.208	0.35	6.7	313	3678	119		
1011-1	0.035	74	0.160	0.267	0.35	5.8	346	9899	49		
1011-2	0.037	74	0.160	0.267	0.35	5.8	346	9364	51.8		
12-1	0.089	76	0.126	0.210	0.35	6.4	301	3383	124.6		
12-2	0.028	76	0.113	0.188	0.35	6.8	287	10245	39.2		
12-3	0.027	76	0.145	0.242	0.35	5.9	319	11829	37.8		
12-4	0.038	74	0.110	0.183	0.35	6.8	279	7349	53.2		
12-5	0.081	76	0.154	0.257	0.35	5.7	328	4046	113.4		
12-6	0.061	76	0.129	0.215	0.35	6.5	313	5132	85.4		
12-7	0.016	75	0.134	0.223	0.35	6.1	305	19073	22.4		
12-8	0.023	75	0.077	0.128	0.35	7.4	213	9249	32.2		
12-9	0.021	75	0.112	0.187	0.35	6.8	284	13540	29.4		
12-10	0.069	75	0.170	0.283	0.35	5.5	349	5059	96.6		
12-11	0.041	74	0.073	0.122	0.35	7.5	204	4985	57.4		
100A	0.048	66	0.138	0.230	0.45	6	397	8280	67.2	28	42
100B	0.022	66	0.132	0.220	0.45	6.4	406	18432	30.8	13	42
100C	0.035	72	0.150	0.250	0.45	5.8	418	11931	49	31	63
200A	0.035	70	0.144	0.240	0.45	5.9	408	11652	49	27	55
200B	0.017	72	0.144	0.240	0.45	5.9	408	23989	23.8	15	63
200C	0.051	72	0.144	0.240	0.45	5.9	408	7996	71.4	45	63
300A	0.049	65	0.162	0.270	0.45	5.6	435	8887	68.6	25	36
300B	0.026	68	0.126	0.210	0.45	6.4	387	14887	36.4	18	49
300C	0.06	72	0.150	0.250	0.45	5.8	418	6960	84	53	63
400A	0.02	72	0.210	0.350	0.45	5	504	25200	28	16	57
400B	0.01	72	0.210	0.350	0.45	5	504	50400	14	8	57
500A	0.036	72	0.162	0.270	0.45	5.6	435	12096	50.4	31	62
500B	0.009	72	0.108	0.180	0.45	6.9	358	39744	12.6	9	71
500C	0.015	72	0.108	0.180	0.45	6.9	358	23846	21	15	71

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5.2 Rational Method

The Rational Method is an empirical runoff formula which has gained wide acceptance because of its simple, intuitive treatment of estimating peak storm runoff. This method relates peak runoff to drainage area, rainfall intensity, and basin surface characteristics by the formula:

$$Q = CiA \tag{5-1}$$

where:

Q = peak runoff rate, in cubic feet per second (cfs).

C = Runoff coefficient representing a ratio of peak runoff rate to average rainfall intensity for a duration equal to the runoff time of concentration;

i = average rainfall intensity in inches per hour; and

A = drainage area in acres; and

The Rational Method is based on the following assumptions:

1. The peak rate of runoff at any point is a direct function of the average uniform rainfall intensity for the estimated runoff time of concentration to the point.
2. The frequency of the peak discharge is the same as the frequency of the average rainfall intensity.
3. The runoff time of concentration is the time required for the runoff to become established and flow from the most hydraulically remote part of the drainage area to the design point under consideration. This assumption applies to the runoff most remote in time, not necessarily in distance.
4. The peak discharge per unit area generally decreases as the drainage area increases, and the intensity of rainfall decreases as its duration increases.

Although the basic principles of the Rational Method generally apply to drainage areas less than 200 acres, common design practice generally limits its use to some lesser area. The Rational Method shall be used for basins up to 100 acres for the Colorado Springs/El Paso County Area. For larger areas, basin storage and subsurface drainage flow cause an attenuation of the runoff so that the rates of flow tend to be overestimated by the Rational Method. In addition, the assumption of uniform rainfall distribution and intensity becomes less appropriate as drainage area increases. Because of the trend for overestimation of flows

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and the additional cost in drainage facilities associated with this overestimation, the application of a more sophisticated runoff computation technique is usually warranted on larger drainage areas. The designer must obtain permission from the appropriate design review agency before applying the Rational Method to areas larger than 100 acres.

5.2.1 Runoff Coefficient, C

The runoff coefficient, C, is a variable of the Rational Method which is least susceptible to precise determination and provides the designer with a degree of latitude to exercise his independent judgment based upon known effecting parameters. The following discussion is intended to provide a guide to promote the uniform selection and application of runoff coefficients.

The runoff coefficient accounts for abstractions for losses between rainfall and runoff which may vary with time for a given drainage area. These losses are caused by intercepting vegetation, infiltration into soils, retention in surface depressions, evaporation and transpiration. In determining this coefficient, different climatological and seasonal conditions, antecedent moisture conditions, and the intensity and frequency characteristics of the design storm should be considered.

Table 5-1 provides runoff coefficients that vary with recurrence frequency. The coefficients were developed using the available rainfall and runoff information in the Denver region and have been adjusted to work in conjunction with the Colorado Springs/ El Paso County area. Use of these coefficients and procedures in other than semi-arid climates may not be valid. However, because the coefficients vary with frequency, no further adjustments are needed for large storms. Adjustments should be made for level of development, surface type, soil type, and surface slope. It is often desirable to develop a composite runoff coefficient based in part on the percentage of different types of surfaces in the drainage area. This procedure can be applied to typical "sample" areas as a guide to the selection of usual values of the coefficient for the entire area.

A composite runoff coefficient is calculated using the relationship:

$$C = \frac{\sum_{i=1}^{n} C_i A_i}{A_t} \qquad (5-2)$$

where:

C_i = individual runoff coefficient corresponding to surface type;

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A_i = area of surface type corresponding to C_i;

A_t = total drainage area for which composite runoff coefficient is applicable;

n = total number of surface types in drainage areas; and

C = the composite runoff coefficient.

The coefficients presented in Table 5-1 are applicable for the initial 10-year storm and for the major 100-year storm. These coefficients, however, are based on the assumption that the design storm does not occur when the ground surface is frozen or covered by melting snow. The designer must exercise good judgement in estimating runoff coefficients for these conditions, if necessary.

5.2.2 Rainfall Intensity, i

Rainfall intensity, i, is the average rate of rainfall, in inches per hour, for a storm of a given duration equal to the estimated runoff time of concentration. Intensity is selected on the basis of design frequency of exceedence, a statistical parameter established by design criteria, and the storm rainfall duration. For the Rational Method, the critical rainfall intensity is the rainfall having a duration equal to the estimated runoff time of concentration for the drainage basin. For the City/County, rainfall intensity for T_c values ranging from 0 to 60 minutes can be determined for the 10-year and 100-year return periods from Figure 5-1.

5.2.3 Runoff Time of Concentration, T_c

One of the basic assumptions underlying the Rational Method analysis is that runoff from the most hydraulically remote point of the drainage basin to the design point under consideration. Runoff time of concentration is usually estimated by calculating travel time through the basin. Overland flow, storm sewer and/or road gutter flow, and channel flow are typical phases of direct flow commonly used in calculating travel time.

Overland Flow

The travel time for overland flow is the estimate in time required for flow to travel from the uppermost part of a drainage basin to a defined channel or inlet of a local storm sewer system. Overland flow can be significant in small basins because a significant portion of time of concentration is due to overland flow. The velocity of overland flow can vary greatly with the surface cover and tillage characteristics. If the slope and land use of the overland flow reach are known, the travel time can be read from figure 5-2 or calculated using the following equation:

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TABLE 5-1

RECOMMENDED AVERAGE RUNOFF COEFFICIENTS AND PERCENT IMPERVIOUS

LAND USE OR SURFACE CHARACTERISTICS	PERCENT IMPERVIOUS	"C" FREQUENCY			
		10		100	
		A&B*	C&D*	A&B*	C&D*
Business					
Commercial Areas	95	0.90	0.90	0.90	0.90
Neighborhood Areas	70	0.75	0.75	0.80	0.80
Residential					
1/8 Acre or less	65	0.60	0.70	0.70	0.80
1/4 Acre	40	0.50	0.60	0.60	0.70
1/3 Acre	30	0.40	0.50	0.55	0.60
1/2 Acre	25	0.35	0.45	0.45	0.55
1 Acre	20	0.30	0.40	0.40	0.50
Industrial					
Light Areas	80	0.70	0.70	0.80	0.80
Heavy Areas	90	0.80	0.80	0.90	0.90
Parks and Cemeteries	7	0.30	0.35	0.55	0.60
Playgrounds	13	0.30	0.35	0.60	0.65
Railroad Yard Areas	40	0.50	0.55	0.60	0.65
Undeveloped Areas					
Historic Flow Analysis- Greenbelts, Agricultural	2	0.15	0.25	0.20	0.30
Pasture/Meadow	0	0.25	0.30	0.35	0.45
Forest	0	0.10	0.15	0.15	0.20
Exposed Rock	100	0.90	0.90	0.95	0.95
Offsite Flow Analysis (when land use not defined)	45	0.55	0.60	0.65	0.70
Streets					
Paved	100	0.90	0.90	0.95	0.95
Gravel	80	0.80	0.80	0.85	0.85
Drive and Walks	100	0.90	0.90	0.95	0.95
Roofs	90	0.90	0.90	0.95	0.95
Lawns	0	0.25	0.30	0.35	0.45

* Hydrologic Soil Group

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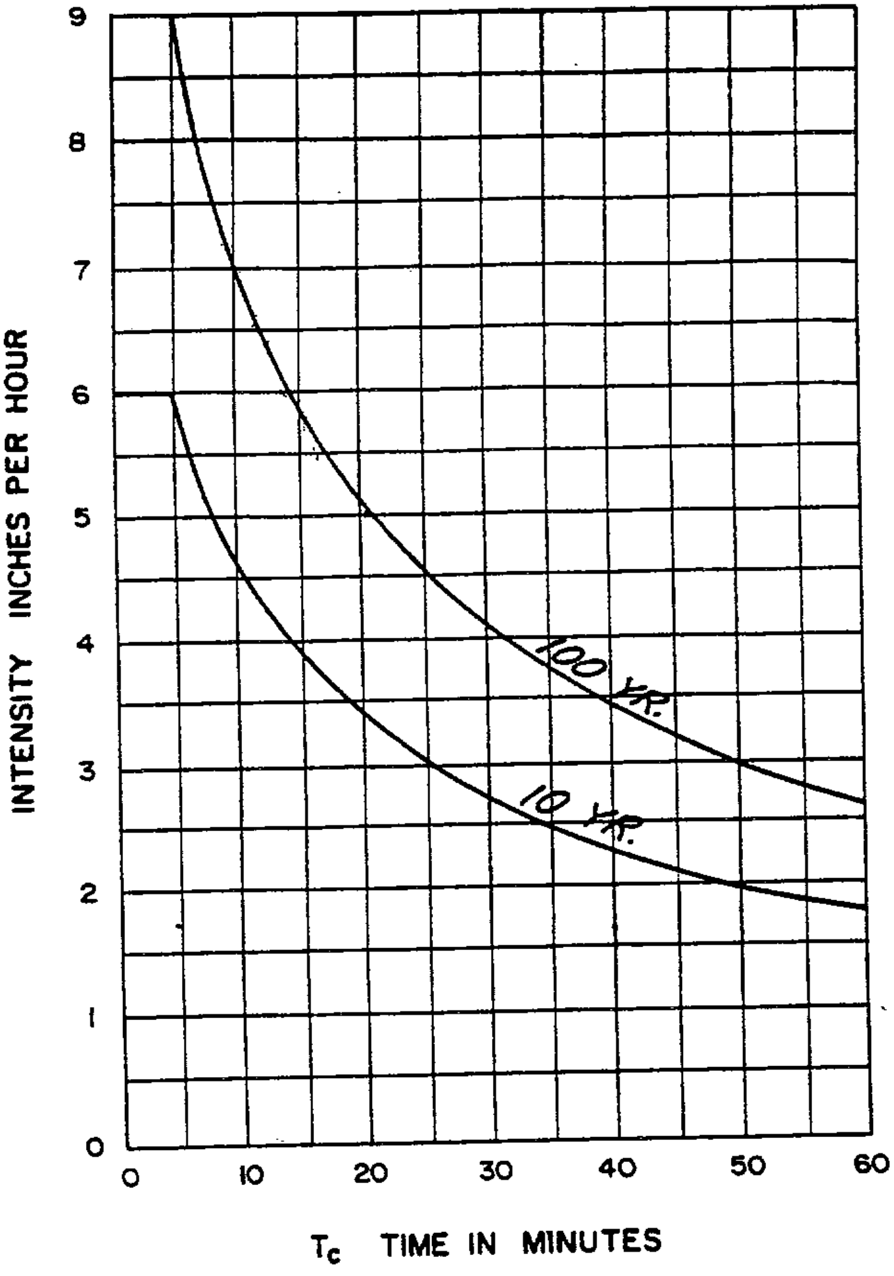

RE: Based upon Pikes Peak area council of governments/ areawide urban runoff control manual.

HDR Infrastructure, Inc.
A Centerra Company

The City of Colorado Springs / El Paso County
Drainage Criteria Manual

Storm Rainfall
Time Intensity-Frequency Curves

Date
OCT. 1987

Figure
5 - 1

APPENDIX D

Conceptual Design of Fishers Canyon Debris Control/ Flood Attenuation Structure

D1.0 INTRODUCTION

The Broadmoor Resort Community is planning for residential development to about 6900 ft elevation on the slope at the base of Fishers Canyon, as shown on Figure D-1. A potential hazard for development on this slope is debris flows which emanate from Fishers Canyon. This appendix presents a conceptual design for a debris control structure to store the debris associated with a design flood, while allowing water to pass. In addition, the structure will reduce discharges downstream through attenuation of flood waters. The structure will be located near the mouth of the canyon and will eliminate the need to design debris flow conveyance structures through the proposed development. The structure will allow safe passage of flood waters downstream and will mitigate the Fishers Canyon debris flow hazard at the fan apex associated with runoff from events up to the 100-year frequency design event.

D2.0 PROJECT DESCRIPTION

A perennial stream flows in the upper part of Fishers Canyon to a point about 600 feet distance and 100 feet elevation below an old water off take structure, which is located in the channel at about elevation 7400 feet. Below this elevation the channel is dry except, apparently, during periods of storm flow. The channel has numerous trees that probably range from 30 to 100 years old, and has very thick underbrush. There are boulders in excess of 20 feet in diameter within the channel, but no evidence of movement of these boulders from where they likely fell from the slopes above. The majority of boulders are less than 6 feet in diameter and the interstices are generally filled with smaller boulders and finer material.

The existing alluvial fan surface has relatively dense vegetation consisting of shrubs and trees, some probably in excess of 100 years old. The exposed soil is granular, containing sand-size particles through boulders several feet in diameter. The interstices of the large material are generally filled with the finer material. Based on observations of the canyon and alluvial fan, we judge them to be relatively stable and the frequency of debris flows to be low.

The rock outcrop above the valley is jointed but does not appear to be particularly unstable. The rock on the eastern flank of Cheyenne Mountain appears more fractured and weathered than within the canyon, perhaps because of the proximity of the eastern flank to the Ute Pass Fault. One large relatively recent (indicated by fresher rock faces) rockfall release scar was observed at the back of the canyon. There was no evidence of recent large rockfall lower in the valley but there are local talus deposits along the valley flanks.

Based on our evaluation of the existing conditions and review of available information, we believe that the debris flow hazard from Fishers Canyon can be effectively managed by the use of an engineered debris control structure near the apex of the fan below the canyon. The structure will be designed to trap the sediment transported by the debris flows while allowing uncontrolled passage of water flows in excess of the stored debris volume. Flood water storage is also provided in excess of the debris storage volume. Flood events up to the 100-year frequency design event will pass through a service spillway riser structure. Larger flood events will pass through a rock riprap lined spillway without eroding the structure. The structure will include an ungated low-level outlet conduit to allow passage of water downstream. A below grade storage area behind the structure will be utilized to trap the majority of sediment. Channel improvements and/or berms will be implemented to control water flows on the fan below the debris control structures to keep flows contained to the "south" channel.

D3.0 HYDROLOGIC AND DEBRIS FLOW TRANSPORT ANALYSIS

The hydrologic, hydraulic and sediment transport analysis associated with the proposed structure is discussed in the following sections.

D3.1 Hydrologic Analysis

At the fan apex, the channel becomes less incised than it is within the canyon and appears to generally convey flows to the southeast. Inspection of available topography and a site reconnaissance suggests that the current (at the time of topographic survey) channelization of the fan would direct nearly all flow from Fishers Canyon to the east-southeast, into or south of the Star Ranch property. The topography shows channels on the fan that trend northeastward, but these channels are generally isolated from the Fishers Canyon channel by one or more drainage divides. At some locations, these divides are shallow and flow could possibly avulse from one drainage to another during periods of extreme runoff, especially if debris and sediment is transported with the flow. Review of available information (Lincoln DeVore 1981) suggests that the major flow paths from Fishers Canyon were to the north of Star Ranch in recent history.

Several hydrologic analyses and reports have been reviewed as part of our evaluation (FLO Engineering, 1995; FLO Engineering, 1996; FLO Engineering, 1997; KLH Engineering, 1982; Kiowa Engineering, 1996; and Muller Engineering, 1991) These reports indicate that the 100-year frequency, 2-hour rainfall is 3.1 inches at this site and runoff from this rainfall should be used for design purposes. The peak water discharge at the mouth of Fishers Canyon is estimated to be 560 cubic feet per second (cfs) for this event (FLO Engineering, 1995). An average sediment concentration of up to 35 percent could be expected during most natural runoff events and the 100 year water flood event would be assumed to transport approximately this much material.

Plans for the Boulders Broadmoor Filing No. 1 and 1A (Kiowa Engineering, 1996) indicates a flow rate of 318 cfs in the "south" channel which flows through the Boulders Broadmoor property indicating a "split" in Fishers Canyon flow paths downstream of the fan apex. It is our opinion that the assumption of a "split" flow into various natural channels can not be guaranteed for the existing condition. The debris control structure will maintain the flows into one flow path in the "south" channel rather than providing a "split" in the flow. This will be done through the use of training berms, channel regrading and riprap lined channels.

A hydrologic model was developed to determine routing and attenuation effects of the proposed structure and to determine peak discharges downstream. The model indicates that the structure will reduce flows at the apex of Fishers Canyon from approximately 560 cfs to 220 cfs during the 100-year frequency design event.

An analysis of downstream structures indicates that the structures located within the Boulders Broadmoor Filing No. 1 and 1A are capable of passing up to approximately 750 cfs. This capacity should be adequate to convey the 100-year peak water flow rate from Fishers Canyon estimated to be approximately 362 cfs at this location.

D3.2 Debris Flow Transport Analysis

The average concentration of sediment transported from the watershed as a result of an infrequent runoff event is expected to be on the order of 30 percent by volume of the water runoff volume. To estimate the volume of debris transported during an infrequent event, the water hydrograph is bulked for the potential average sediment concentration of the event. The bulking factor is given as BF=1/(1-Cv) where Cv is the average sediment concentration by volume. In this way the BF also accounts for the pore space incorporated in the debris when it is deposited. Previous estimates of the 100-year frequency runoff event indicate a peak flow of 560 cubic feet per second (cfs) and a total runoff water volume of approximately 29 acre-feet. Therefore, the sediment volume transported to the apex of Fishers Canyon is estimated to be approximately 12.3 acre-feet and the debris control structures should be designed to store this volume.

The size distribution of the debris transported depends on the sizes of materials in the source area and the power of the flow transporting the sediment. Because the channel within Fishers Canyon is relatively steep and narrow, the ability to carry a large amount of debris is evident. The available size of sediment within the watershed ranges from fine particles to large boulders (in excess of 6 feet diameter). Based on a design flow rate of 560 cfs, the velocities within the Fishers Canyon channel upstream of the proposed structure may be in excess of 20 feet per second (fps), and at these velocities, boulders up to 6 feet diameter could be transported. However, the majority of sediment transported will be smaller materials consisting of sands through cobble (12-inch) sizes.

Due to the high velocities of expected flows within the channel during the design event, a great deal of destruction of vegetation could also be expected. Trees and brush within the channel could be uprooted during the design flow and transported downstream. In addition, debris generated on steep side slopes may incorporate significant amounts of vegetation (trees and shrubs) before entering the channel. The engineered debris flow control structure will be designed to control this vegetation as well as transported sediment.

D3.3 PMF Analysis

The structure has been preliminary classified as a Class III structure based on State of Colorado State Engineer's Office (SEO) guidelines and as such the structure has a downstream hazard which could include extensive property damage. Therefore, the structure will be designed to safely pass the Probable Maximum Flood (PMF). The PMF is defined to be the largest possible event which could occur based on atmospheric conditions of the area. The PMF was determined by estimating runoff resulting from the Probable Maximum Precipitation (PMP) event. The PMP was estimated from HMR-55A (National Weather Service, 1988) and was determined to be approximately 26 inches for a 6-hour duration and 35.5 inches for a 24-hour duration.

The U.S. Army Corps of Engineers HEC-1 computer program was utilized to determine runoff from the PMP event. Input for the model included the PMP distributed using a hypothetical storm distribution which determines the most critical duration for a storm and thus determines the maximum peak runoff possible. Other input included a unit hydrograph for the watershed calculated from U.S. Bureau of Reclamation procedures (USBR, 1989), infiltration rates based on available soils and vegetation data and the upstream watershed drainage area.

The model estimated that the critical duration storm is between 6 and 12 hours with a peak rainfall depth of 29 inches. The peak PMF determined from the model upstream of the proposed structure is approximately 8800 cfs. The structure is designed to safely pass this flow rate downstream through a 200-foot wide rock riprap lined spillway section within the dam embankment.

D3.4 Dam-break Analysis

The effects of a hypothetical dam-break failure on downstream areas was estimated utilizing the National Weather Service program, DAMBRK as sold by the Boss Corporation under the name BOSS DAMBRK. The program simulates a hypothetical dam failure hydrograph based on parameters input by the user and routes the hydrograph downstream utilizing unsteady flow hydraulics. Although a dam failure is not likely for this structure, simulating the failure and potential incremental damages downstream allows for better emergency planning should such an unlikely failure occur.

Hypothetical dam failures were modeled for both a "sunny day" scenario in which the reservoir has no inflow and is assumed to be full and for failure during the PMF event. For the sunny day analysis, dam failure was assumed to occur as a result of a piping failure originating at mid-height of the dam and ultimately extending for a width of 100 ft and for the full height of the dam embankment. For the PMF analysis, an overtopping breach of similar width (100 ft wide extending to embankment toe) was applied. The breach dimensions assumed are within the range of breach dimensions for earth dams listed by the U.S. Bureau of Reclamation's Guidelines to Decision Analysis (ACER Technical Memorandum No. 7) and a range of breach developments times were assessed (0.25-5.0 hours).

Model results indicated a sunny day breach would result in peak flows of approximately 360 cfs at the dam. A breach occurring during a PMF event would increase the peak flow from 8350 cfs to 8570 cfs, an increase of 220 cfs or 3 percent.

Incremental downstream flood depths for conditions with the dam failure would increase slightly over that of the PMF with no dam failure, though the incremental damages associated with the dam break would be insignificant.

D4.0 GEOPHYSICAL INVESTIGATION

Geophysical techniques were utilized as part of the geotechnical evaluation for the Fishers Canyon Debris Control Structure. The objectives of the geophysical survey were to:

- Estimate colluvial thickness
- Aid characterization of the bedrock surface
- Obtain seismic velocity information to facilitate estimation of subsurface excavatability.

Generally, this information was sought for specific areas near two proposed sites for the debris control structure. The geophysical technique used to accomplish these tasks was seismic refraction.

D4.1 Seismic Refraction Method

Seismic refraction for engineering applications is most often used to infer geological boundaries as indicated by interfaces with seismic velocity contrasts. Refraction data may be used to estimate:

- Thickness of alluvial and colluvial deposits
- Depth to the water table and/or competent subsurface layers
- Configuration of the alluvial-bedrock contact
- Relative excavatability (based on seismic velocities)

The seismic refraction method consists of transmitting seismic energy into the ground and recording the arrival of direct or refracted sound waves at various distances along the earth's surface. The seismic energy travels in each layer with a characteristic seismic compressional velocity that is dependent on the density, compressibility, pore space, and fluid content of the geologic layer. By measuring seismic velocities, as inferred from the recorded first-arrival travel times, and by determining seismic velocity contrasts, an interpretation can be made of the configuration and depths of subsurface seismic layers. These seismic layers often correlate to geologic units, but ambiguities can arise where weathered bedrock or colluvium with large boulders are encountered. Considering the potential for ambiguity, seismic bedrock can be defined as the seismic layer detected at the greatest depth in which less rippable or non-rippable materials may be encountered. An example of the seismic refraction method is provided in Figure D.2.

A limitation of the refraction method involves the primary assumption made in refraction interpretation that the seismic velocity of the subsurface increases with depth. If the velocity of a layer is less than that of the layer immediately overlying it, the travel time as a result of the lower layer will be slower and not easily measured, yielding a first-arrival travel time on the recorded data of the faster layer. A decrease in velocity with depth can cause layers to be shadowed by upper, faster layers and hidden or undetected, thus leading to depth estimates that may be in error. This scenario is possible at the Fishers Canyon site, where granite boulders within soft weathered zones can be encountered.

Another limitation of the method is that a refractor must be sufficiently thick to be detected. The thickness required depends on the layer depth, the velocity contrast with overlying and underlying layers, and the field parameters utilized during data acquisition and recording.

To record seismic refraction data, a seismic source, cables, geophones, and a seismograph are required. The seismic source may be a sledge hammer, buried explosives or an elastic wave generator, depending on the depth of investigation and attenuation properties of the near-surface material. Geophones implanted in the ground translate vibrations into an electrical signal displayed on the seismograph. Data can be output on hard copy records and/or saved on personal computer (PC)-compatible disks.

Data collected can be processed and analyzed with one of several interactive seismic refraction interpretation packages. These packages, which operate on a PC, make all necessary topographic corrections, construct time-distance plots, allow calculation of apparent layer velocities, and calculate depths at each geophone location. From the results, a final cross-section of the seismic layers is produced. Cross-sections from individual seismic spreads can be tied to available geologic or geophysical borehole information, as well as to other seismic spreads, to make a final geologic interpretation of the entire surveyed area.

D4.2 Seismic Refraction Field Program and Data Processing

Two seismic traverses (totaling approximately 500 linear feet) over 2 different investigation areas were surveyed during the seismic field program of September 2, 1997. The final location of each seismic traverse was chosen based on the survey objectives, and considering the general investigation areas. The investigation areas for the seismic work included an upper canyon area site and a lower canyon area site. Relative elevations of each geophone location were determined using a hand level in the field. The relative elevations were then adjusted to approximate elevations using a topographic map.

Seismic refraction data were collected using a 24-channel, signal-enhancing, Geometrics Strataview Model R24 seismograph. Various geophone spacings were used for the seismic lines depending on the expected depth to bedrock, as well as the investigation area to be covered. Two geophone spacings were used, 15 feet and 12 feet. For each seismic source, seismic energy was produced by a sledge hammer. Each seismic spread had five seismic sources. Seismic sources were used at both ends of each spread for forward and reverse travel times and in the middle of the spread to increase near-surface velocity control. Additionally, offset sources were also used to enhance coverage of the bedrock surface.

Processing of the seismic refraction data involved the construction of a time-distance plot for each seismic spread. To construct the time-distance plots, the first compressional wave arrival at each geophone location was plotted versus the source-to-geophone distance. Velocities of the seismic layers were calculated based on the slope of the best-fit lines through the plotted compressional-wave time-distance data. The intercept of each velocity slope at time zero was used to calculate depths to particular seismic interfaces.

Interpretation of refraction survey data involved the computation of average velocities over surveyed volumes of subsurface material. For the upper seismic layer in which the direct seismic wave arrived at the geophone first, the velocity observed was the true average velocity between the energy source and the geophone. For deeper interfaces in which the refracted seismic wave arrived at the geophone first, the velocity observed is usually an apparent velocity. If the refractor surface is flat-lying, the apparent velocity will be equal to the true average velocity. If, however, the refractor surface is dipping or has a variable surface, the true average velocity can be estimated utilizing the apparent velocities obtained from the data collected from both the forward and reverse seismic energy sources.

Time-distance plots were constructed and interpreted using the software program GREMIX, an interactive seismic-refraction processing routine developed by Interpex Limited. GREMIX allowed interactive plotting of each travel time plot, selection of velocity slopes, and identifications of forward and reverse shot pairs. With elevation information from each geophone, the program calculated seismic layer thicknesses for each geophone travel time. Figure 1 provides a sample output cross-section with a figure explanation and key. Final interpretations are displayed for each seismic line in cross-section form in Figures D.3 and D.4. Note that distances portrayed in the cross-sections are slope distances.

D4.3 Seismic Refraction Results

Two seismic refraction lines were over different investigation areas as part of the geotechnical evaluation for the Fisher's Canyon Debris Control Structure. Based on interpretation of the seismic refraction results, several generalizations can be made. Seismic layer 1, which is part of the overburden materials, likely consists of unconsolidated soil and colluvial materials. Seismic layer 2, which is also generally part of the overburden materials, likely consists of colluvial materials combined with weathered bedrock and boulders. Seismic layer 3 is the deepest identifiable refractor layer and likely corresponds to granitic bedrock materials. Significantly weathered bedrock materials with some boulders within seismic layers 3 are indicated along line SL2. This interpretation is shown on Figures D.3 and D.4 and summarized on Table D.1.

TABLE D.1

SEISMIC REFRACTION RESULTS

Seismic Line	Seismic Layer	Velocity Range (feet/second)	Thickness of Seismic Layer (feet)	Depth to most Competent Layer Detected (feet)
SL1	1	680 - 960	1 - 6	
	2	2,100 - 3,160	28 - 44	
	3	7,740 - 9,360		30 - 47
SL2	1	720 - 1,980	2 - 13	
	2	2,480 - 5,520	9 - 42	
	3	8,270 - 12,040		16 - 55

Utilizing seismic velocity measurements obtained from the refraction survey, estimates of rippability can be made. Caterpillar Inc. has several publications relating seismic velocity to rippability for various rock types. Table D.2 summarizes the relative rippability based on the use of a Caterpillar D-9 unit for the Fishers Canyon refraction lines.

TABLE D.2

SUMMARY OF RIPPABILITY

Seismic Line	Seismic Layer	Estimate of Rippability
SL1	1	Rippable
	2	Rippable
	3	Marginally Rippable to non-rippable
SL2	1	Rippable
	2	Rippable
	3	Non-rippable

D5.0 DESIGN CRITERIA

Based on our understanding of the needs of the Broadmoor Resort Community and our site reconnaissance, data review, and geophysical investigation, the Fishers Canyon debris control/flood attenuation structure will be designed to meet the following criteria:

1. Design for the 100-year frequency, 2-hour rainfall of 3.1 inches.
2. Store debris from the design storm (100-year frequency event) and allow water to pass downstream.
3. Safely pass water and debris for events in excess of the 100-year event.
4. Excavation depth should be limited to 30 feet to minimize excavation in bedrock and the need for blasting.
5. Provide access for maintenance and periodic cleaning of the structure.
6. Direct all flow to the south of Star Ranch and limit peak discharges to maximum capacity of existing downstream structures.
7. Minimize visual impact.
8. Minimize operational and maintenance costs.

The following values have been adopted for design of the Fishers Canyon debris control structure:

Q_{10} = 190 cfs

Q_{100} = 560 cfs (water only)

Q_{100} = 1120 cfs (bulked for sediment)

$Q_{PMF} \approx$ 8800 cfs (water only)

Water Volume = 28.8 acre-feet

Avg. Sediment Concentration ~ 30%

Avg. Bulking Factor = 1.43

Peak Sediment Concentration ~ 50%

Peak Bulking Factor = 2.00

Volume of Sediment = 12.3 acre-feet

Impact Factor of Safety = 1.4

D5.1 State Dam Safety Requirements

The proposed structure will fall under the jurisdiction of the Colorado State Engineer's Office (SEO), Department of Water Resources. As such, a full permit application including plans and specifications will be submitted to the SEO for approval prior to construction. The structure will be inspected on an annual basis and will be maintained by the Broadmoor Resort Community Homeowner's Association.

D6.0 CONCEPTUAL DESIGN EVALUATION

Alternative types of engineered structures were evaluated conceptually for implementation in Fishers Canyon, including crib dams, porous rock dams, conventional earthfill dams, steel grid control structures, debris deflectors, and below grade storage basins. The alternatives were evaluated for potential implementation either within the canyon or near the apex of the alluvial fan below the canyon.

Fishers Canyon is narrow and relatively steep, and flow upstream of the fan apex is constrained to a singular channel. Debris flow control sites in the canyon have the advantage of having granitic bedrock at shallow depth on the abutments and foundation. Disadvantages include the limited and difficult access and the relatively small storage volume behind structures of a given height.

Debris control structures could be built on the alluvial fan to work in conjunction with structures in the canyon or to work independently. Structures built on the fan should be built at the apex of the fan, near the mouth of the canyon, where a single channel is still reasonably incised.

The principal advantages of sites at the apex of the fan include easier access for construction and maintenance and a larger area to allow impoundment of the design debris volume, even with relatively low height structures. The principal disadvantage is that a longer structure would need to be constructed to control flood flows that might jump the channel bank if the channel becomes blocked by debris. A debris dam or a debris basin, or a combination, could be constructed at this location. Training berms or channel regrading should be constructed further downstream on the fan surface as needed to direct overbank flows back into a single channel.

The preferred alternative is a debris control structure built at the apex of the alluvial fan because the location is more suitable for storing the required sediment volume and it is more readily accessed for construction and maintenance.

D7.0 DEBRIS CONTROL STRUCTURE CONCEPTUAL DESIGN

To satisfy the design criteria listed in Section 4.0 and keep the total debris flow hazard mitigation costs low, the proposed structure consists of a debris basin and dam constructed at about elevation 7170 at the apex of the Fishers Canyon alluvial fan. Figure D.5 presents the conceptual design of the preferred structure. The structure will have the capacity to store the debris volume associated with the 100-year frequency event as well as attenuate flood waters up to the 100-year frequency design event. A low level outlet with a debris rack will be provided to drain the structure and limit downstream flow rates. In addition, a service spillway riser and rock riprap lined emergency spillway will be provided to pass larger flood frequency events.

The proposed structure will consist of an excavation of about 30 feet depth with selected excavated material placed as an embankment dam along the downstream side of the basin. The embankment will be constructed of 8-inch minus natural and processed material with rock riprap lining of the upstream face and spillway. The final design will include a basin floor sloped subparallel to the existing topography.

The structure will be designed to channel all flow to the existing "south" channel which continues south of the Star Ranch property and through the Boulders Broadmoor Filing No. 1 and 1A. To prevent erosion of the downstream channel and maintain stability of flow paths during extreme runoff events, downstream channel controls will be implemented. The extent of the downstream controls should extend to approximate contour 7,000 feet elevation. These controls may include lining the channel with rock riprap or concrete, regrading of the channel and/or construction of training dikes. The final plans and specifications for the structure will show details and extents of the downstream controls.

The structure will attenuate flows such that downstream flow rates will be reduced. A low level outlet structure and service spillway riser structure will limit peak discharges downstream for events up to and including the 100-year frequency design event.

D8.0 REFERENCES CITED

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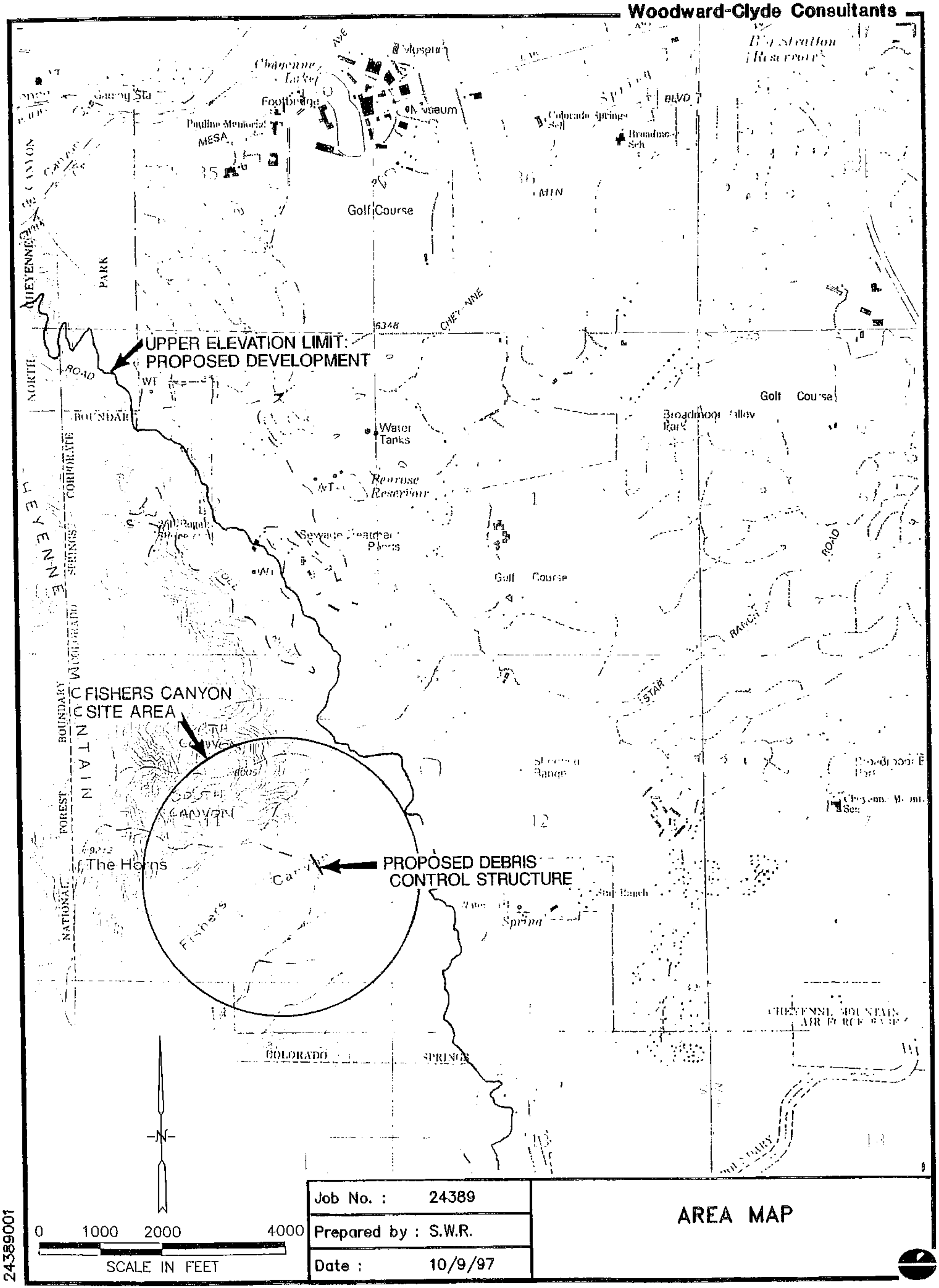
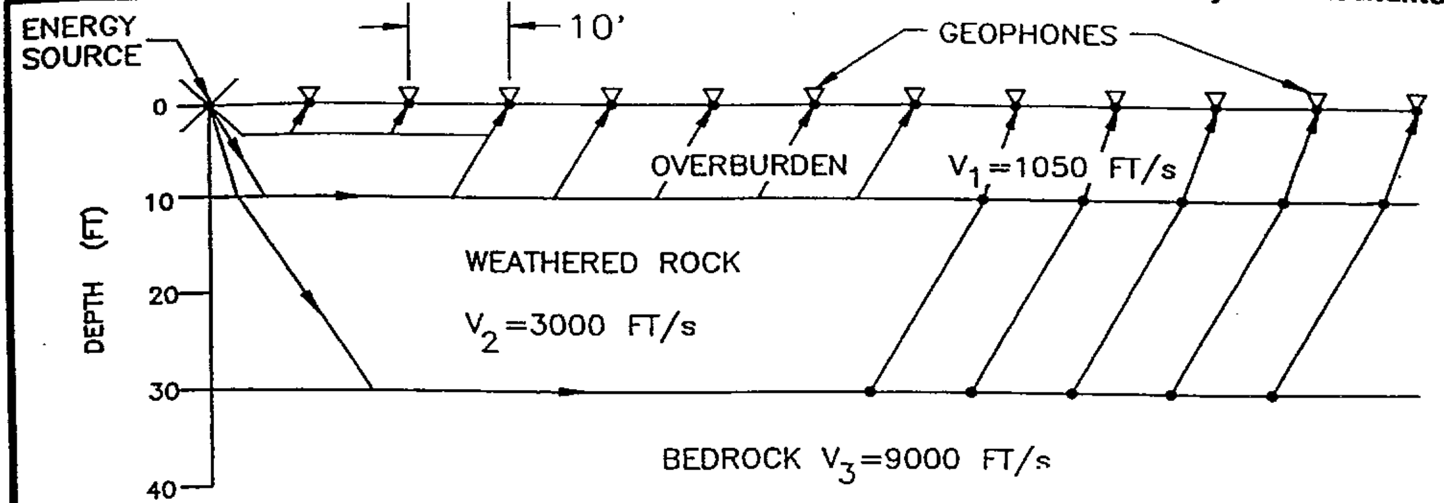


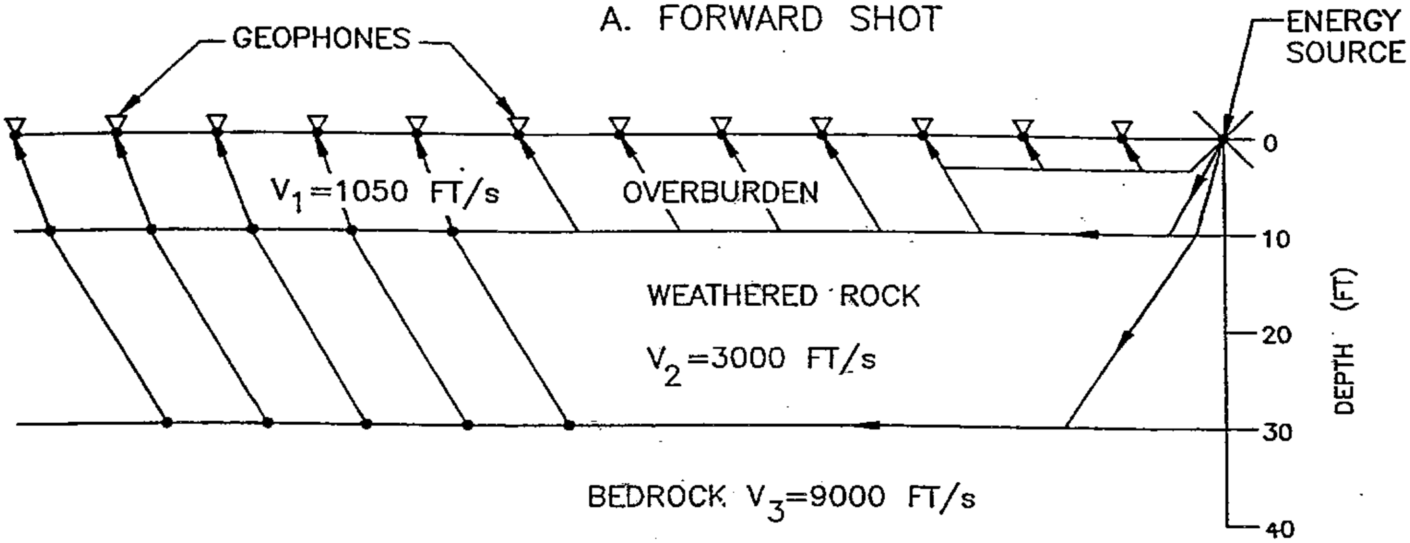
Job No. :	24389	AREA MAP
Prepared by :	S.W.R.	
Date :	10/9/97	

24389001

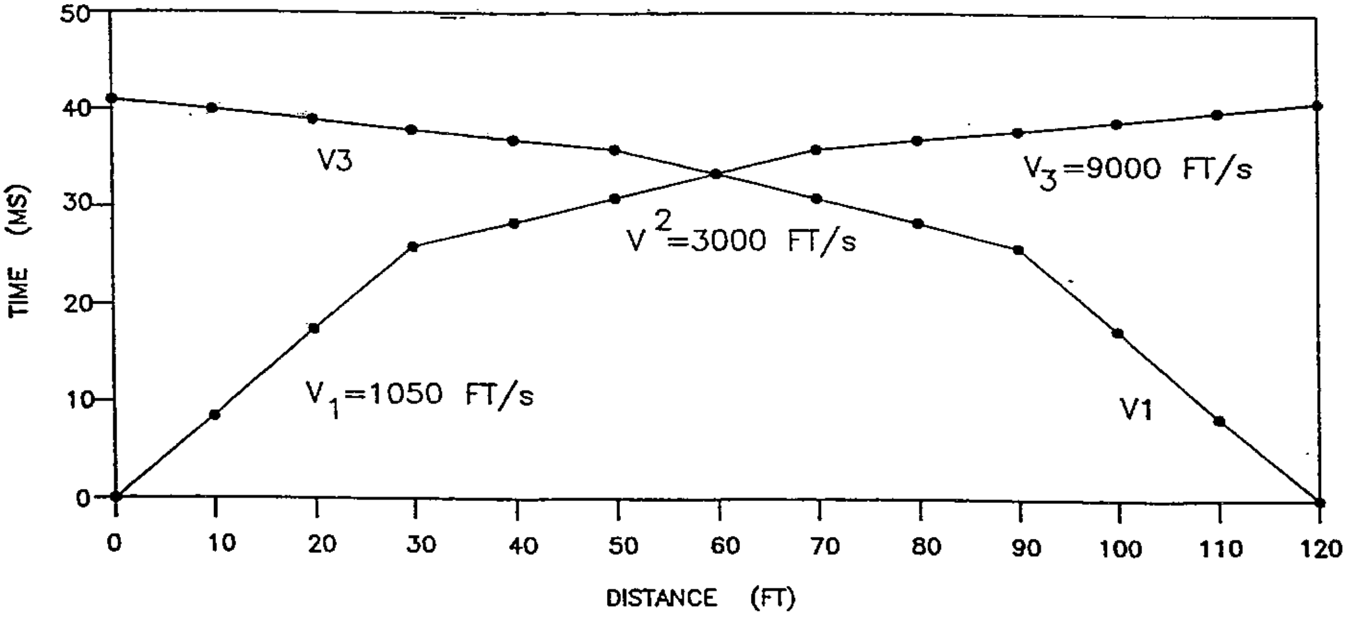
FIG. D.1



A. FORWARD SHOT



B. REVERSE SHOT

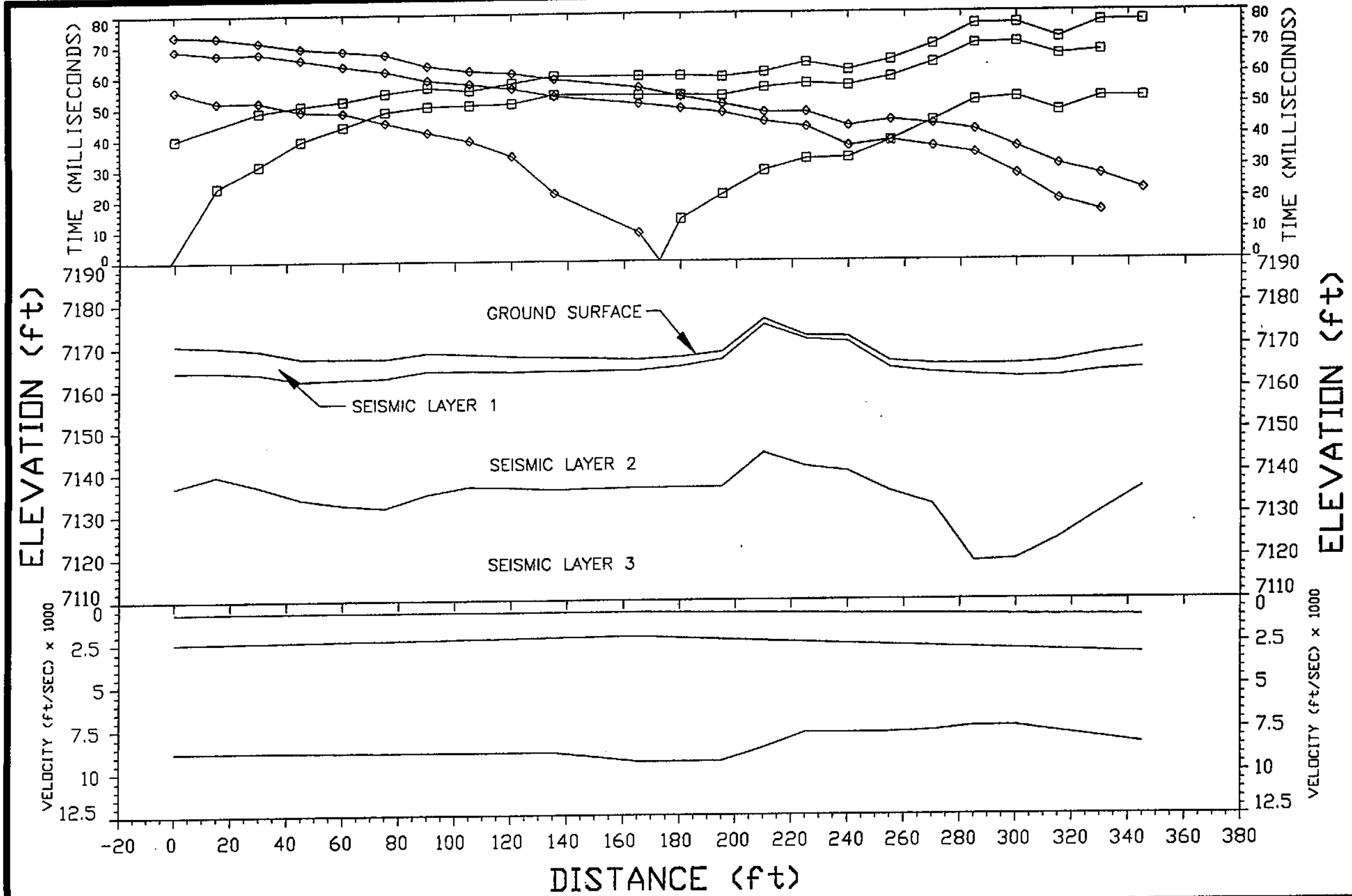


C. TIME–DISTANCE PLOT OF FORWARD AND REVERSE SHOTS

Job No. : 24389
Prepared by : S.W.R.
Date : 12/8/97

AN EXAMPLE OF THE SEISMIC REFRACTION METHOD

FIG. D.2



for: Project Number 24389

by: Woodward Clyde Consultants

Data Set0101

Date: Sept. '97

Equipment: Geometrics R24

Spread: SL1

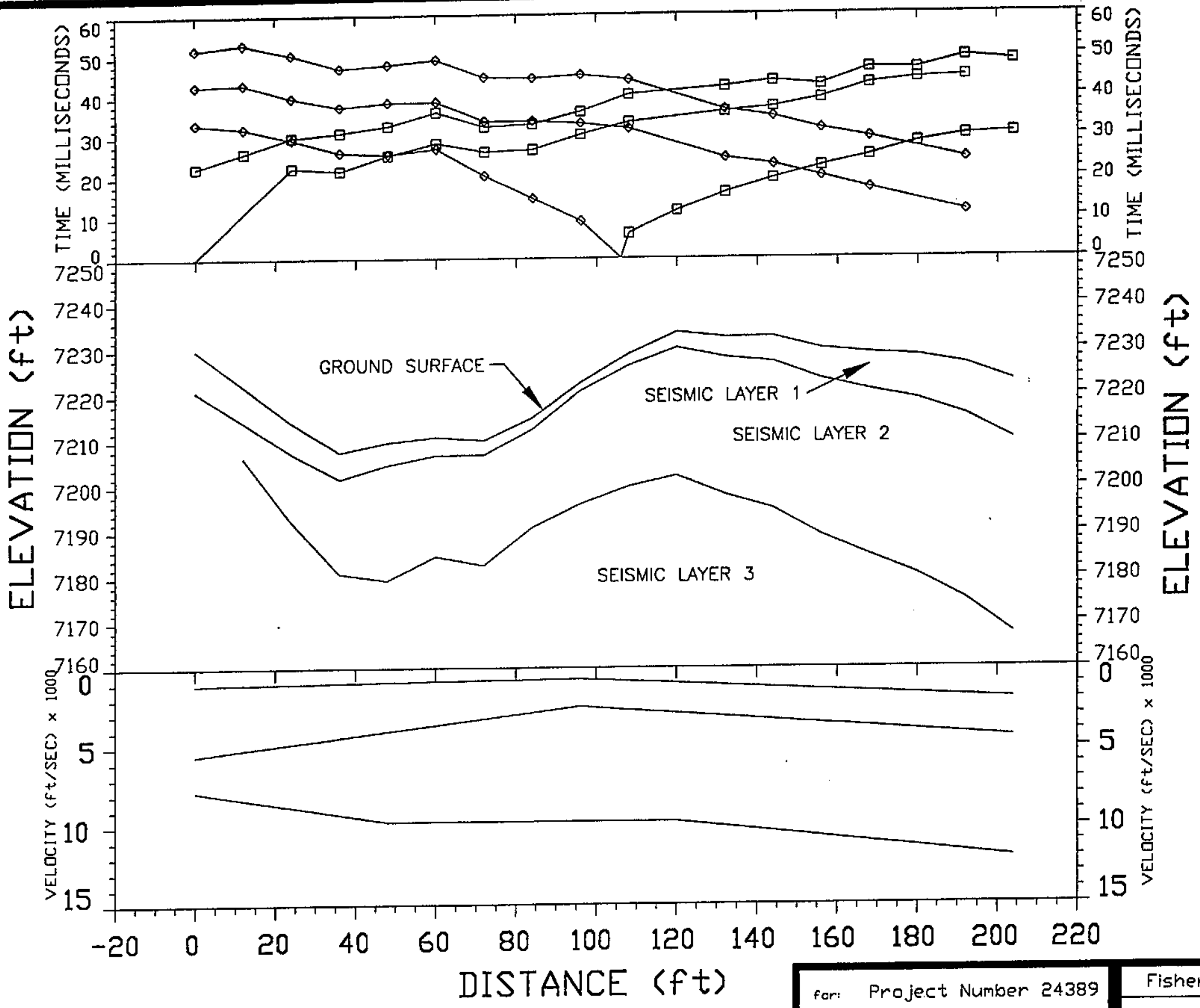
Fisher Canyon Debris Flow

Lower Structure Alignment

Seismic Refraction Traverse

Azimuth: n/a

FIG. D.3



for: Project Number 24389

by: Woodward Clyde Consultants

Data Set0201

Date: Sept. '97

Equipment: Geometrics R24

Spread: SL2

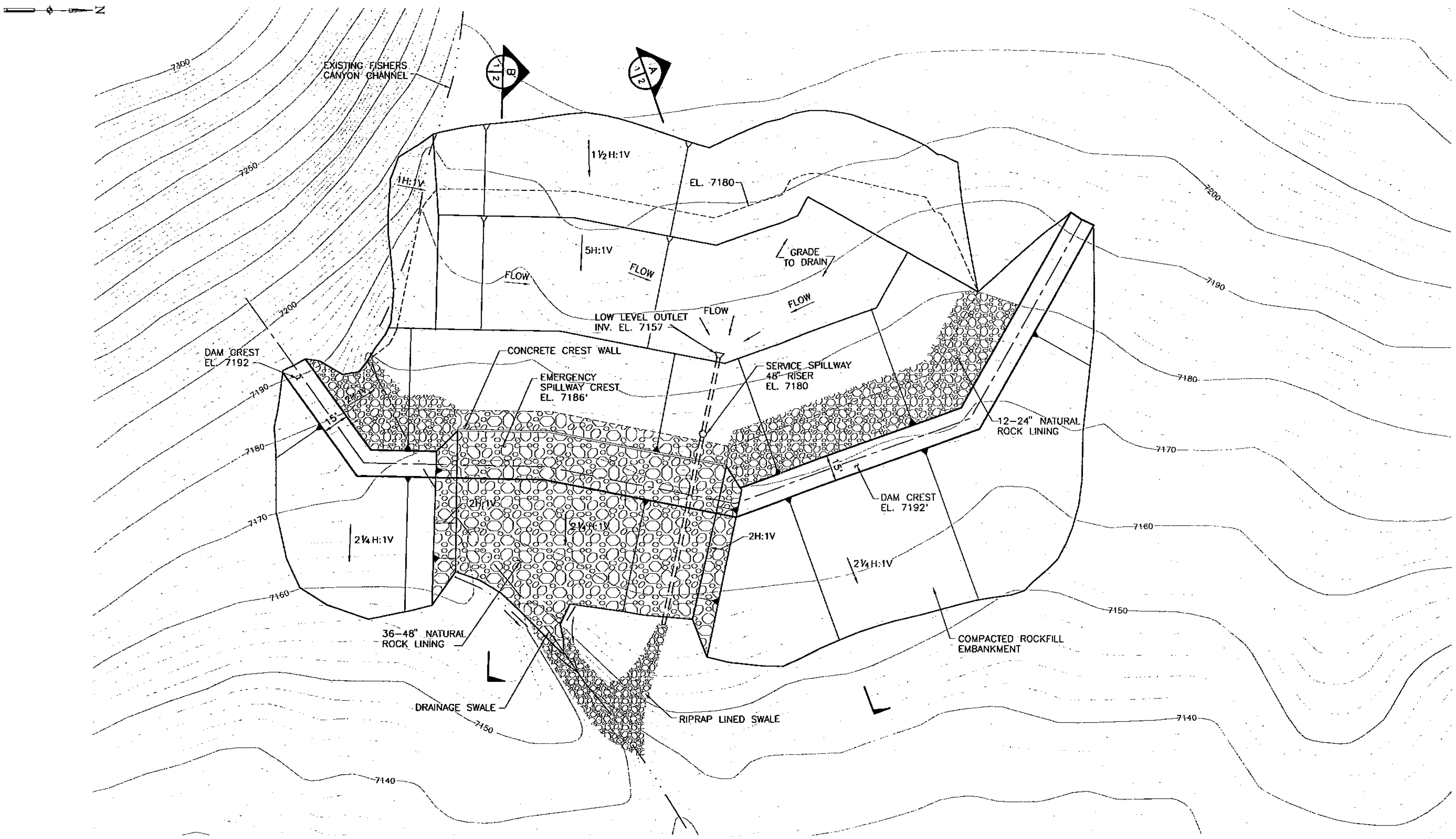
Fisher Canyon Debris Flow

Upper Structure Alignment

Seismic Refraction Traverse

Azimuth: n/a

FIG. D.4



PLAN

0 30 60 90
SCALE IN FEET

**CONCEPTUAL PLAN
NOT FOR CONSTRUCTION**

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WARNING
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DESIGNED –
DRAWN –
CHECKED –
PEER REVIEWED –
PROJECT MANAGER –
DATE –

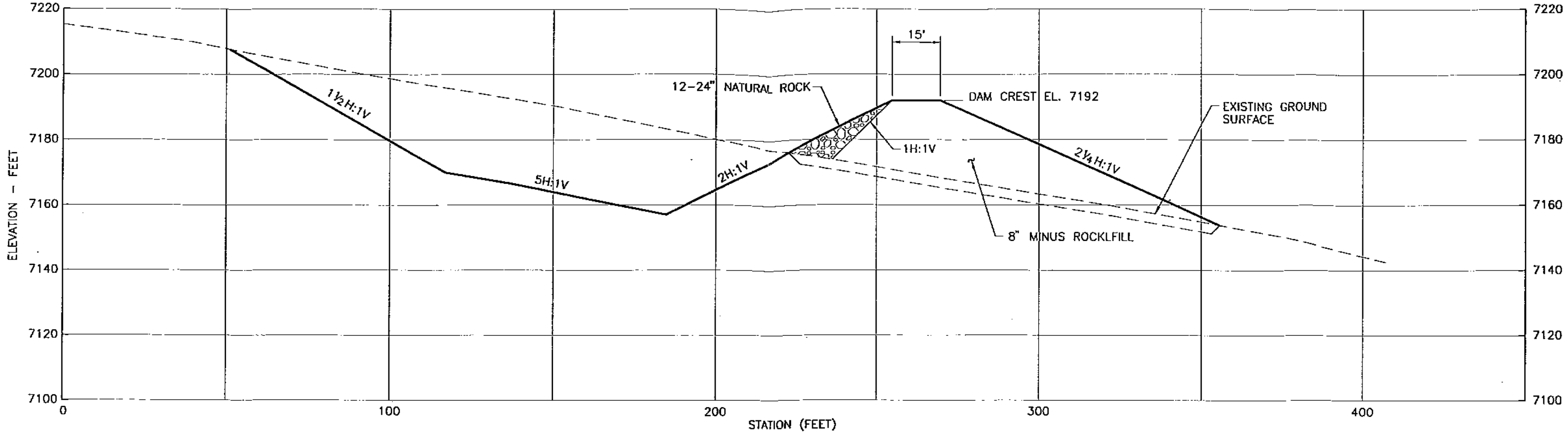
BROADMOOR

FIGURE 1
PLAN OF DEBRIS BASIN

REVISION △0
PROJECT –
DRAWING –
SHEET – OF –

FILE # BRD-F1	OPPER. –	PROJ. # 24389	LOC. DENVER	SEND TO VDH
SCALE –	DATE 2/11/98	TASK # 500	PROJ. BROADMOOR	PHONE 740-3836

FIG D5a



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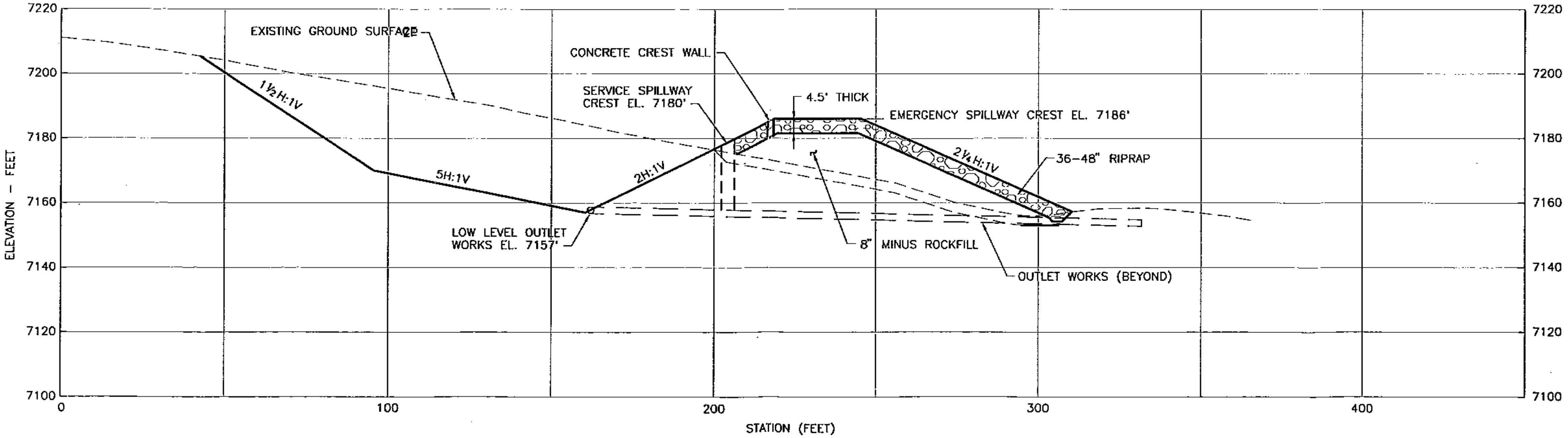

SPILLWAY SECTION

CONCEPTUAL PLAN NOT FOR CONSTRUCTION

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BROADMOOR

FIGURE 2
TYPICAL CROSS-SECTIONS OF DEBRIS BASIN

REVISION 0
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DRAWING -
SHEET - OF -

FILE # BRD-F2 | OPPER. - | PROJ. # 23603 | LOC. DENVER | SEND TO VDH
SCALE 1=20 | DATE 2/12/98 | TASK # | PROJ. BROADMOOR | PHONE 740-3836