Feasibility Study

I-70/CHAMONIX ROAD

November, 1996

Prepared for

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CONTENTS

Feasibility Study

I-70/CHAMONIX ROAD

SUMMARY

Congestion at the interchange of Interstate Highway 70 and Chamonix Road will be nearly eliminated when a pair of modern roundabouts on both sides of the freeway are built next year. The Town will not need to widen the undercrossing.

The interchange will operate at Level of Service A with present base flows. It will have ample capacity to operate at Levels of Service B and C even if present flows increase by more than fifty percent. Crash frequency and severity are expected to decrease following construction of the project.

ROUNDABOUTS AT WEST VAIL

The Town of Vail built North America's first modern roundabout interchange at Main Vail (I-70/Vail Road) in 1995, thus nearly eliminating traffic congestion at what had been the Vail Valley's most heavily impacted interchange. Following a series of meetings with residents over the summer of 1996, the Town decided to convert West Vail (I-70/Chamonix Road) into a modern roundabout interchange. Construction is expected to be completed in 1997. The design and analysis contained in this report were made available to the Town prior to completion of this report, and the Town's decision to proceed with the project was based partly on this information.

West Vail is now the most heavily impacted interchange in the Vail Valley. With flows approaching capacity much of the time, the interchange is subject to unacceptable delay when ~~special events cause~~ surges in traffic demand. At the closely spaced ramp and frontage road intersections, which are regulated by STOP signs, drivers are sometimes confused as to who should stop and who has the right of way.

PROJECT DESCRIPTION

At West Vail two 150-foot-diameter 6-leg roundabouts will be built (see Appendix A). All entries to both roundabouts will have two lanes, with two exceptions: on both roundabouts the southbound Chamonix Road entries will have only one lane.

The circulatory roadways will be 30 feet wide through both roundabouts, with one exception. In front of the 34-foot-wide westbound South Frontage Road entry to the south roundabout, the circulatory roadway will be 34 feet wide. Both roundabouts are designed to accommodate a 65-foot-long tractor and semitrailer.

Visibility limits to vegetation and signs are given in the drawing of Appendix A titled, "Clear View Areas." Within the central islands the outer 30.5-foot-wide margins will be kept clear of tall objects to provide adequate forward visibility, but a central area 29 feet in diameter may be used for landscaping or public art of any desired height.

Splitter islands will be notched to allow pedestrian refuges. Following modern guidelines, crosswalks will not be marked. Walkways will be designed where necessary as part of the landscape plan to align with the pedestrian refuges in the splitter islands. A six-foot-wide walk will follow the west side of Chamonix Road. Along the east side of Chamonix Road a 10-foot-wide bike road will be provided for cyclists and pedestrians. Behind the row of bridge columns the bike road will widen to 12 feet. It will link a 10-foot-wide bike road to be built along the north side of North Frontage Road with a pair of bike lanes striped along the south side of South Frontage Road. Where the bike lanes of South Frontage Road follow alongside the south roundabout, they will be separated from the roundabout by a six-inch curb. Bicyclists and pedestrians will cross the south leg of Chamonix Road south of the splitter island.

Since there is barely room now for both the ramps and the frontage road between the freeway and Gore Creek, space for a new 150-foot-diameter roundabout must be developed by building large structures. Space for the ramps to cut into the side slopes of the freeway will be provided by use of retaining walls. A wider bridge will permit the south side of the roundabout to span Gore Creek.

TRAFFIC PERFORMANCE

The performance of the roundabouts was estimated using the computer application RODEL. (See Appendix D for an explanation of RODEL.) RODEL estimates average delay in minutes per vehicle. By use of a spreadsheet, RODEL estimates were converted to average delay in seconds per vehicle and to the corresponding levels of service (see Appendix E). The *Highway Capacity Manual* relates levels of service to average delay for the whole intersection according to the following table .

LEVEL OF SERVICE FROM AVERAGE STOPPED DELAY AT INTERSECTION
Taken from Table 9-1 of the *Highway Capacity Manual*

STOPPED DELAY (SEC/VEH)	LEVEL OF SERVICE
d<=5	A
5<d<=15	B
15<d<=25	C
25<d<=40	D
40<d<=60	E
60<d	F

HCM Roundabouts?

Both roundabouts will operate at Level of Service A with present traffic. The roundabouts were designed to allow a traffic increase of at least fifty percent because it is thought that some longevity will be necessary to justify the substantial investment required for this project. The improved capacity will accommodate traffic surges of an unknown amount, perhaps fifty percent or more, which presently occur at various times each year.

The design objective of allowing a fifty percent increase in existing flows will be exceeded. The following percent increases in existing traffic will be possible without exceeding average stopped delay of 30 seconds per vehicle on any leg (a measure of practical capacity), estimated at the 85th percentile.

ROUNDABOUT	A.M.	P.M.
West Vail North	146%	56%
West Vail South	67%	56%

With the percent increases in traffic given above, both roundabouts will operate at Level of Service B in the morning peak hour and at Level of Service C in the evening peak hour. Levels of service are presented in the table below.

	AVERAGE DELAY (Seconds Per Vehicle)				LEVEL OF SERVICE			
	North R.		South R.		North R.		South R.	
TRAFFIC DEMAND	A.M.	P.M.	A.M.	P.M.	A.M.	P.M.	A.M.	P.M.
100% of Base Flows*	2.5	3.9	3.4	3.8	A	A	A	A
Increased Base Flows**	11.5	23.4	7.6	16.4	B	C	B	C

* "Base Flows" in this report refers to design flows developed by the Town of Vail in the summer of 1995.

** "Increased Base Flows" refers to 100% of base flows plus the percent increases of the first table given above.

SAFETY

Roger D. Gilpin, of the Colorado Department of Transportation, prepared a report of all crashes at both the Main Vail and West Vail interchanges with Interstate Highway 70 over the three-year period of 1991-93. Appendix C contains the portion of his report that pertains to West Vail.

Fifty-six crashes were reported at the west Vail interchange over the three-year period. Of these crashes, 40 were intersectional. The remaining 16 crashes would not be affected by the modern roundabouts proposed to replace the existing ramp and frontage road intersections.

At the two Chamonix Road intersections which will be replaced by the north roundabout 17 crashes were reported in the study period. At the two intersections which will be replaced by the south roundabout 23 crashes were reported during the study period.

Seventy percent of the 40 intersectional crashes (28 crashes) were rear-end crashes, many of them involving vehicles sliding on ice into stopped vehicles. The roundabouts will not do anything to prevent icy conditions, but they will greatly reduce the number of vehicles stopped in queue. The potential for crashes between vehicles which are stopped and vehicles behind them which can not stop will be reduced as the roundabouts reduce queuing.

During the study period there was one pedestrian crash. There were no motorcycle crashes and no bicycle crashes. Only three of the 40 crashes involved injuries. Thirty-seven were property-damage-only crashes.

It is estimated that the safety performance of modern roundabout improvements to West Vail will be similar to the safety performance of Main Vail's modern roundabouts. During the first twelve months of modern roundabout service, from October 1, 1995 to September 30, 1996, total crashes at Main Vail decreased by 19 percent compared to the average number of crashes per year over the three previous 12-month periods. The percentage reduction, 19 percent, is exactly equal to the percentage reduction forecast in the August 1994 feasibility study for that interchange. Injurious crashes have fallen by 75 percent, to only one in the

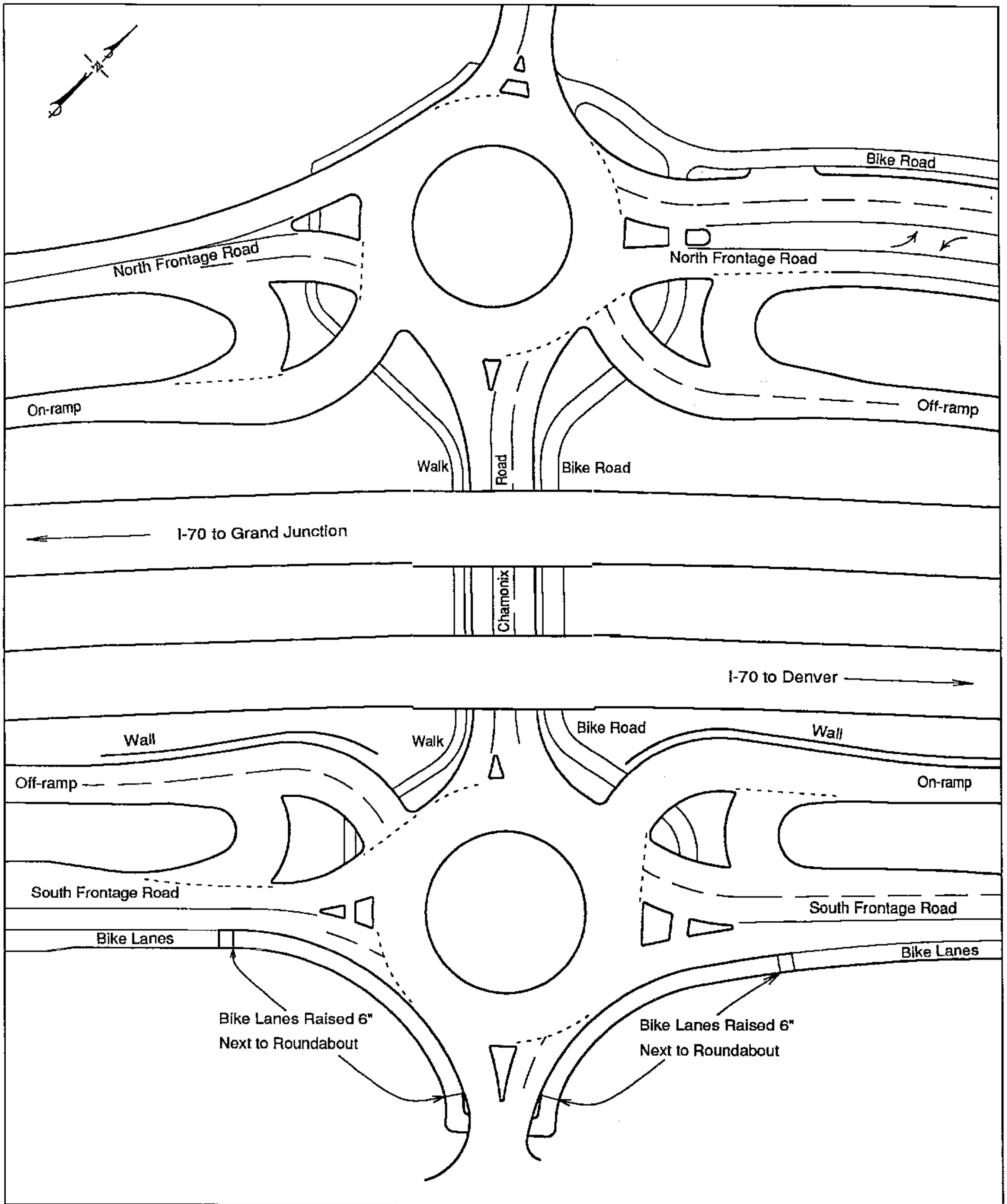
12 months since construction of the roundabouts from an average of four injurious crashes per year in the previous three years.

CONCLUSION

The modern roundabout interchange to be built at West Vail next year will, more than any possible alternative, impart high capacity, low delay, and safety to the cramped, six-leg stop-sign-regulated intersections on both sides of the freeway. The roundabouts will bring order and beauty to Vail's west entrance. The interchange will become a source of pride over future years to the people of Vail and to all who contribute to the project.

APPENDIX A

Proposed Interchange Layouts



Ourston & Doctors

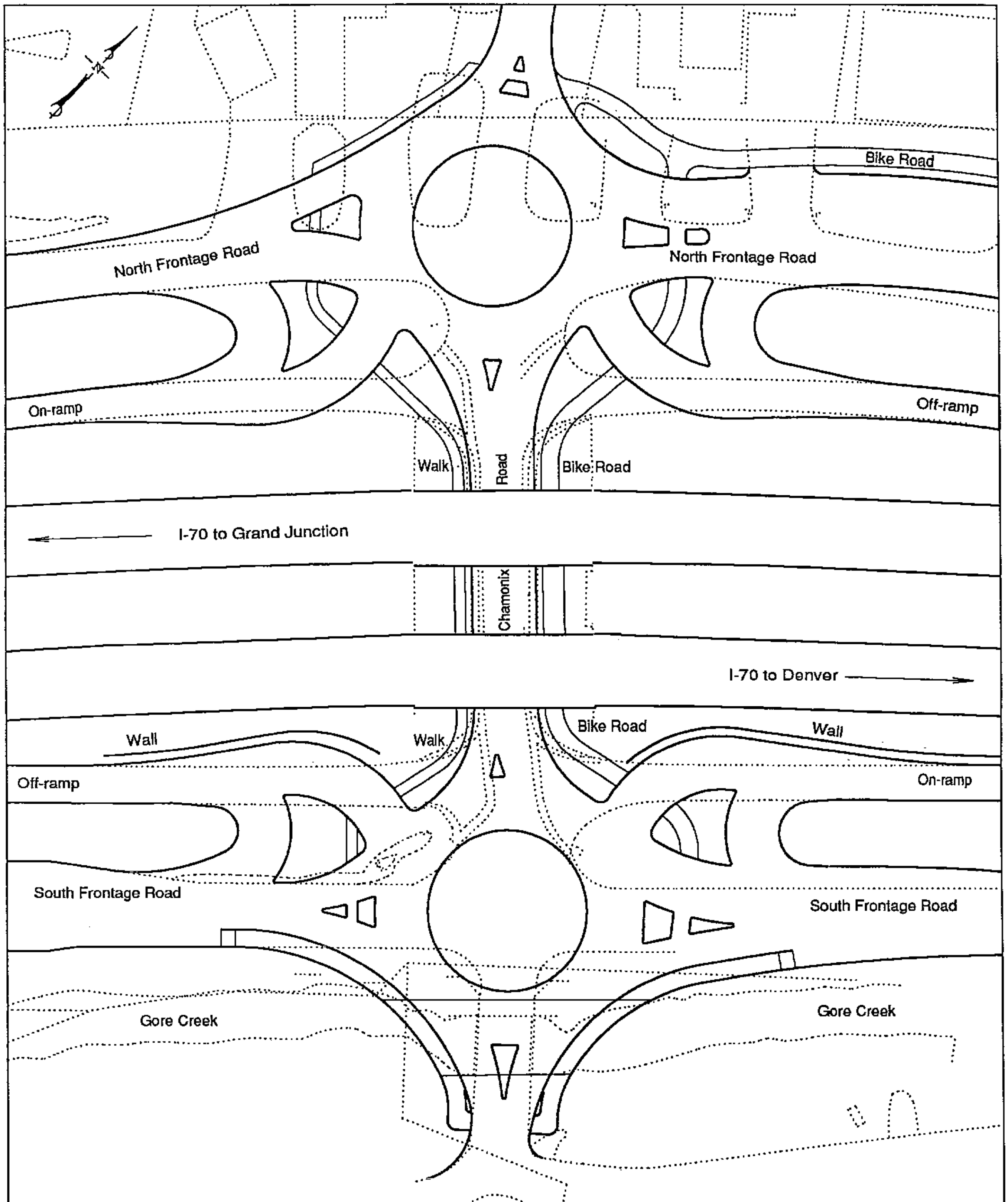
MODERN ROUNDABOUT INTERCHANGES

5290 Overpass Road #212 Santa Barbara, CA 93111

I-70/Chamonix Road

Vail, Colorado

November 11, 1996 *Scale: 1"=80'*



Ourston & Doctors

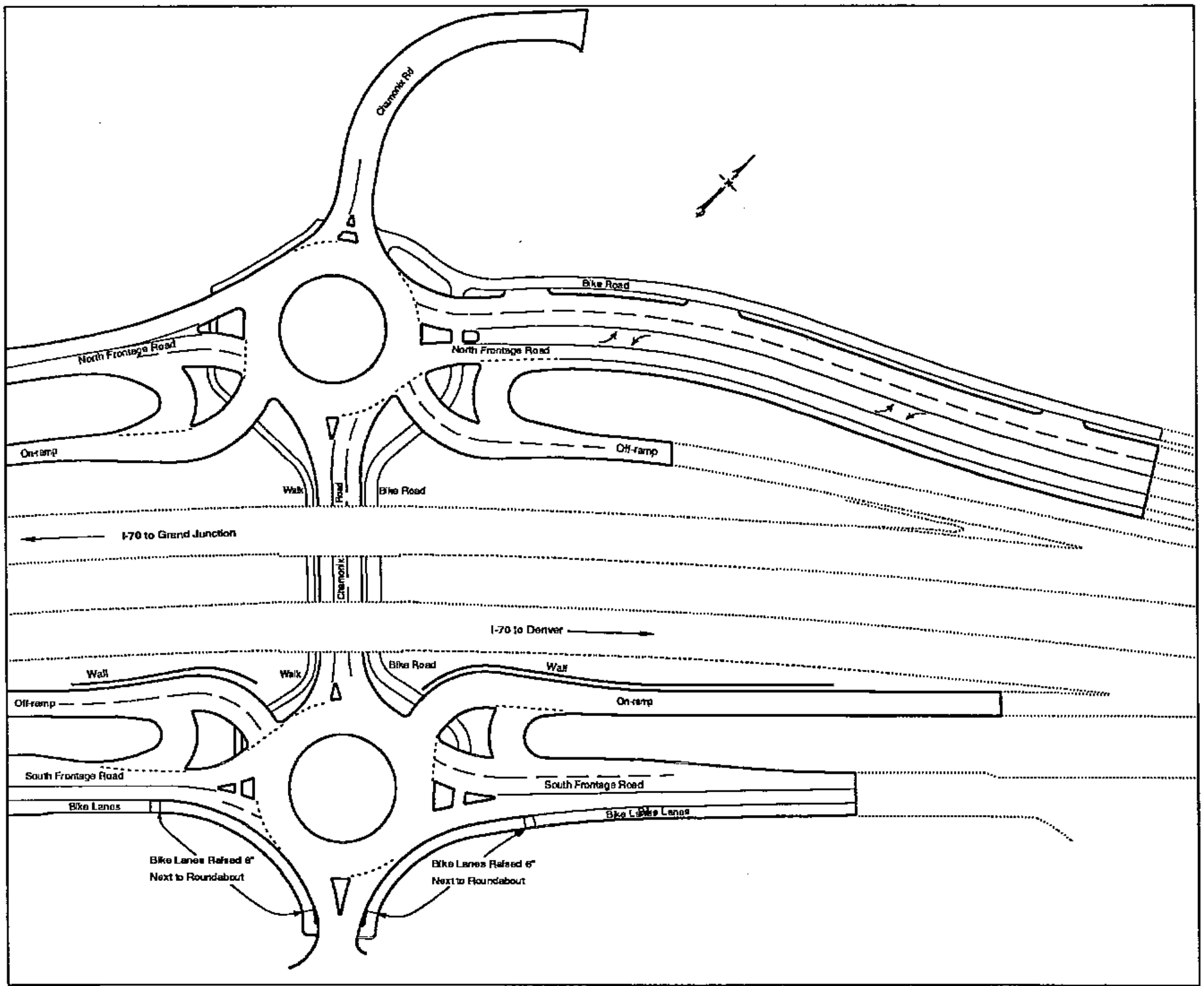
MODERN ROUNDABOUT INTERCHANGES

5290 Overpass Road #212 Santa Barbara, CA 93111

I-70/Chamonix Road

Vail, Colorado

November 5, 1996 *Scale: 1"=80'*



Ourston & Doctors

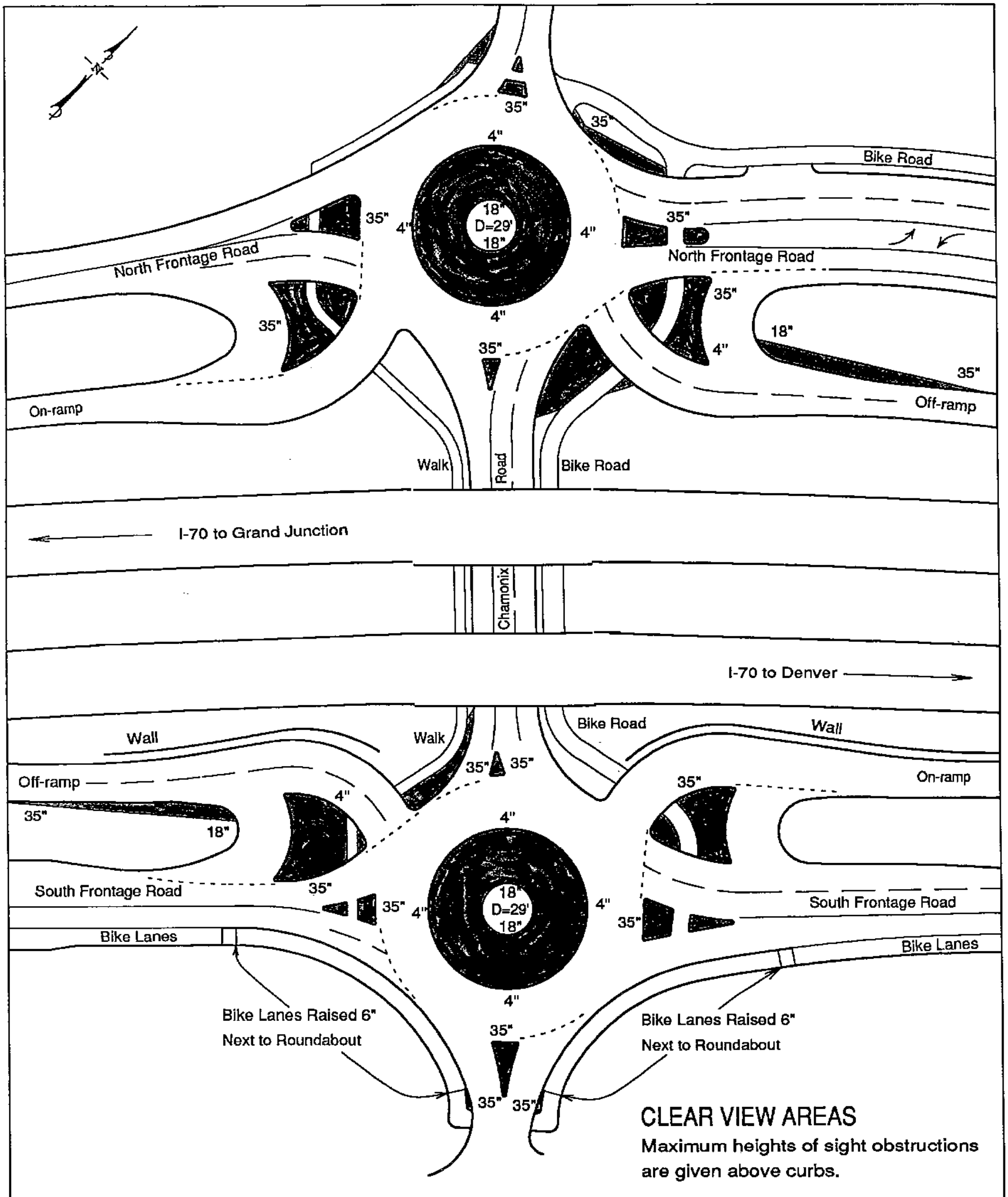
MODERN ROUNDABOUT INTERCHANGES

5290 Overpass Road #212 Santa Barbara, CA 93111

I-70/Chamonix Road

Vail, Colorado

November 5, 1996 *Scale: 1"=150'*



CLEAR VIEW AREAS

Maximum heights of sight obstructions are given above curbs.

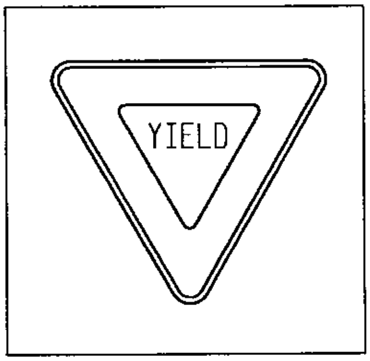
Ourston & Doctors	*I-70/Chamonix Road*
MODERN ROUNDABOUT INTERCHANGES	*Vail, Colorado*
5290 Overpass Road #212 Santa Barbara, CA 93111	*November 5, 1996* *Scale: 1"=80'*

APPENDIX B

Modern Roundabout or Nonconforming Traffic Circle?

MODERN ROUNDABOUT OR NONCONFORMING TRAFFIC CIRCLE?

Unlike nonconforming traffic circles, modern roundabouts conform to modern roundabout guidelines. Among other important new features, modern roundabouts have yield at entry, deflection, and (often) flare, as illustrated below.



YIELD AT ENTRY

MODERN ROUNDABOUT

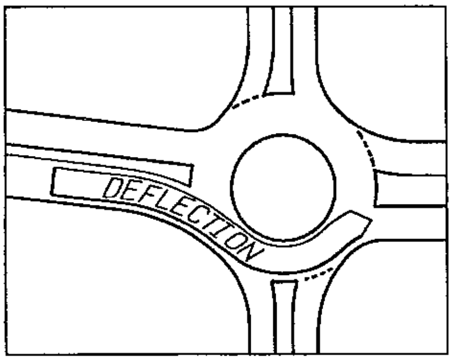
Entering traffic yields to circulating traffic.

- Circulating traffic always keeps moving.
- Works well with very heavy traffic.
- No weaving distance necessary. Roundabouts are compact.

NONCONFORMING TRAFFIC CIRCLE

Entering traffic cuts off circulating traffic.

- Circulating traffic comes to a dead stop when the circle fills with entering traffic.
- Breaks down with heavy traffic.
- Long weaving distances for merging entries cause circles to be large.



DEFLECTION

MODERN ROUNDABOUT

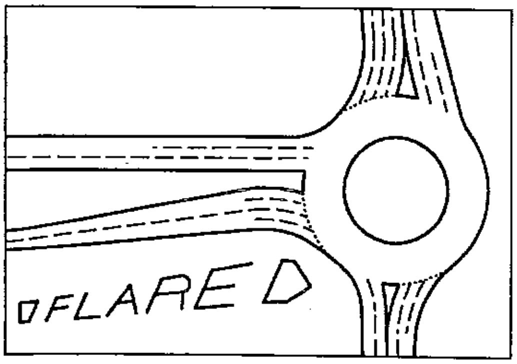
Entering traffic aims at the center of the central island and is deflected slowly around it.

- Slows traffic on fast roads, reducing accidents.
- Deflection promotes the yielding process.

NONCONFORMING TRAFFIC CIRCLE

Entering traffic aims to the right of the central island and proceeds straight ahead at speed.

- Causes serious accidents if used on fast roads.
- Fast entries defeat the yielding process.



FLARE

MODERN ROUNDABOUT

Upstream roadway often flares at entry, adding lanes.

- Provides high capacity in a compact space.
- Permits two-lane roads between roundabouts, saving pavement, land, and bridge area.

NONCONFORMING TRAFFIC CIRCLE

Lanes are not added at entry.

- Provides low capacity even if circle is large.
- For high capacity, requires multilane roads between circles, wasting pavement, land, and bridge area.

APPENDIX C
West Vail Accident History

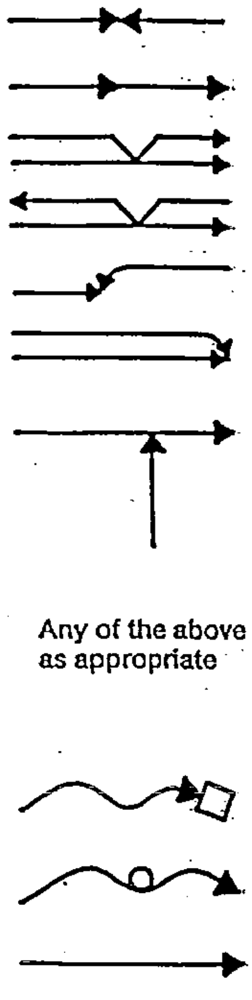
STAFF TRAFFIC AND SAFETY PROJECTS BRANCH

TYPICAL COLLISION DIAGRAM LEGEND FOR MOTOR VEHICLE TRAFFIC ACCIDENTS

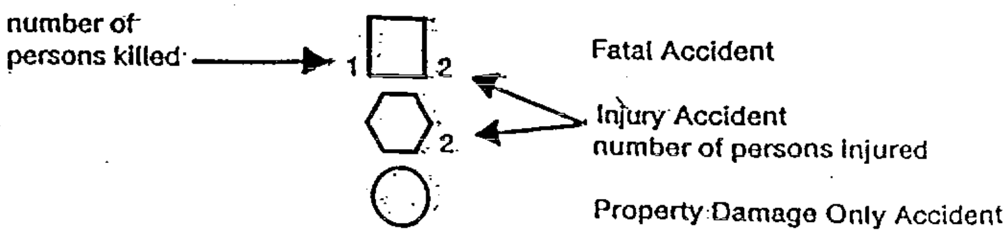
ACCIDENT LOCATION

On-roadway | Off-roadway (right) | Off-roadway (left)

ACCIDENT TYPES	SYMBOL
HO - Head-on	HO
RE - Rear-end	RE
SS - Sidewsipe-same direction	SS
SO - Sideswipe-opposite direction	SO
AT - Approach turn	AT
OT - Overtaking turn	OT
BS - Broadside	BS T or AN (type indicated)
T - Train	
AN - Animal	
PC - Parked car	PC, P or B — Any of the above as appropriate
P - Pedestrian	
B - Bicycle, Motorized bicycle	
FO - Fixed object	FO or O (type indicated)
O - Other object	
OTR - Overturning	OTR
ONC- Other non-collision	ONC (type indicated)



ACCIDENT SEVERITY



COLORADO DEPARTMENT OF TRANSPORTATION

SUMMARY OF MOTOR VEHICLE TRAFFIC ACCIDENTS

File # 680.070.02

Date June 30, 1994

Sheet 1 of 4

Description: SH 70 (I 70) at the West Vail (Chamonix Rd.) Interchange

Milepoint: 173.32 to:

Period: January 1, 1991 to: January 1, 1994

I. NUMBER OF ACCIDENTS REPORTED

One-car accidents	9
Two-car accidents	39
Three or more cars	8
Total	56

II. SEVERITY

Fatal accidents	0
Injury accidents	6
Property damage only	50
Total	56
Persons killed	0
Persons injured	12

III. LIGHT

Daylight	39
Dark, roadway not lighted	
Dark, roadway lighted	17

IV. ADVERSE CONDITIONS

Weather	
Raining	1
Snowing	26
Road	
Wet	2
Snowy	6
Icy	34

V. LOCATION

On-roadway accidents	48
Off-roadway accidents	8
Total	56

VI. TYPES OF ACCIDENTS

Non-collision accidents	
Overturning	1
Other non-collision	2
Collision accidents	
Pedestrian	1
Broadside	8
Head-on	
Rear-end	34
Sideswipe S.D.	3
Sideswipe O.D.	
Approach turn	
Overtaking turn	
Parked car	1
Train	
Bicycle	
Motorized Bicycle	
Domestic animal	
Wild animal	
Fixed object	6
Other object	
Total	56

COMMENTS:

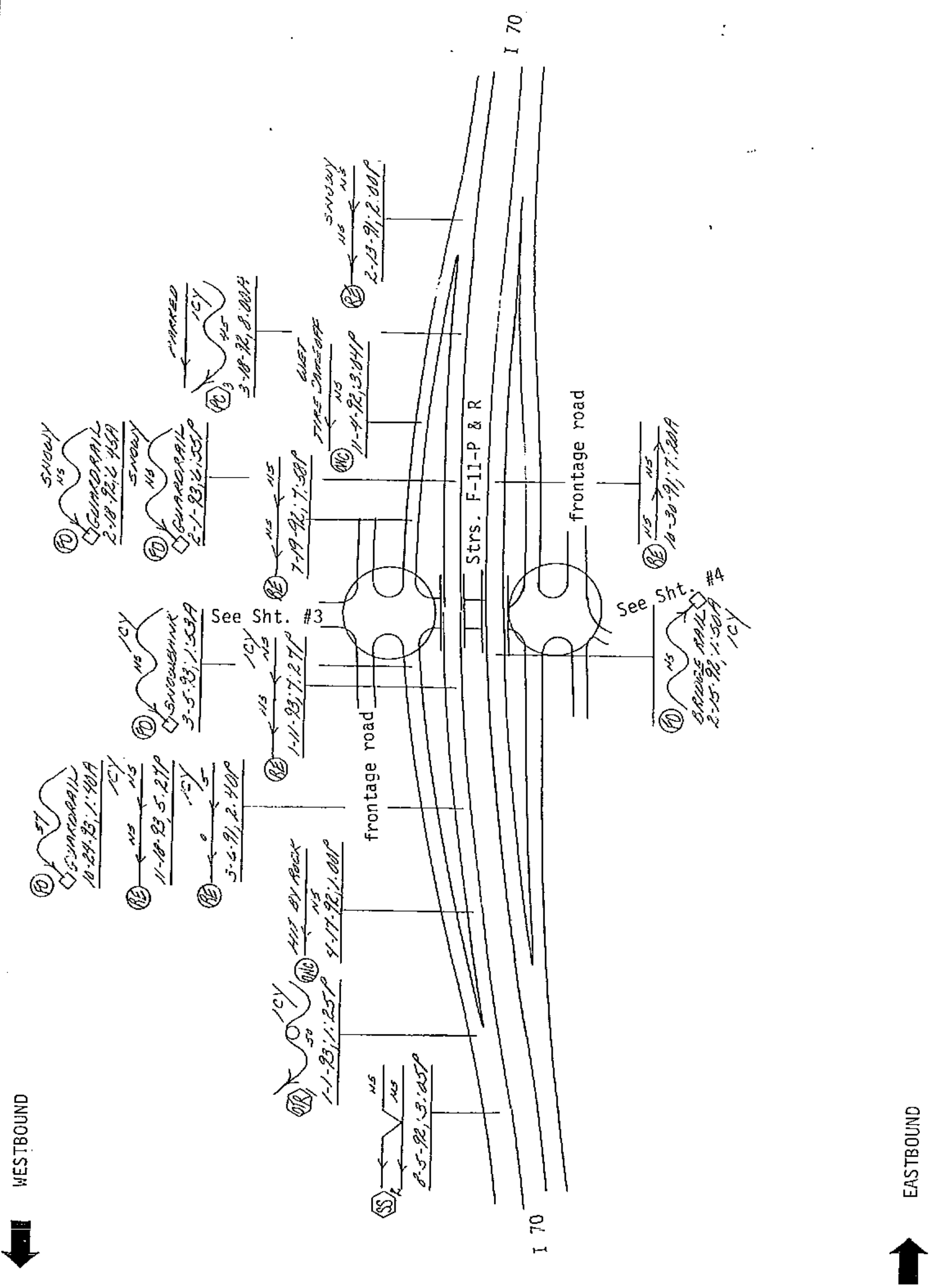
COLORADO DEPARTMENT OF TRANSPORTATION
TRAFFIC ACCIDENT LOCATIONS

File NO.	880.070.02
Date	June 30, 1994

S.H. NO. 70	District III	Period January 1, 1991	to January 1, 1994	Sheet 2	of 4		

Description: SH 70 (I 70) at the West Vail (Chamonix Rd.) Interchange

Milepoint 173.32 to



NOTE: Date, time, speed of vehicles, fixed objects struck, and adverse driver and road surface conditions shown for each accident. NS = not stated

CDOT Form #406 6/92

COLORADO DEPARTMENT OF TRANSPORTATION

TRAFFIC ACCIDENT LOCATIONS

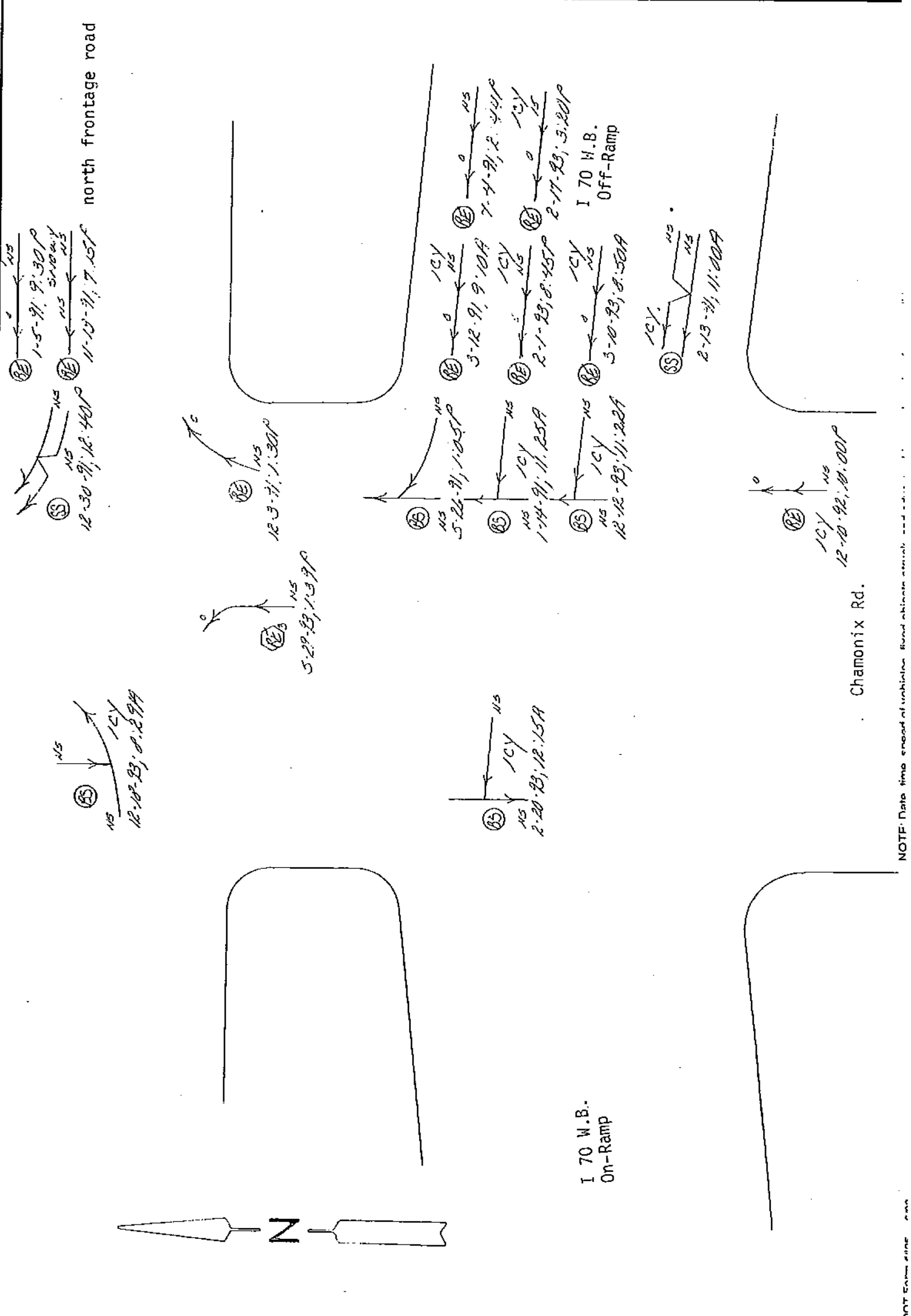
File NO. 880.070.02

Date June 30, 1994

S.H. NO. 70 | District III | Period January 1, 1991 to January 1, 1994 | Sheet 3 of 4

Description SH 70 (I 70) Westbound Ramps and north frontage road at the Intersections with Chamonix Rd. in Vail

Milepoint 173.32 to



COLORADO DEPARTMENT OF TRANSPORTATION

TRAFFIC ACCIDENT LOCATIONS

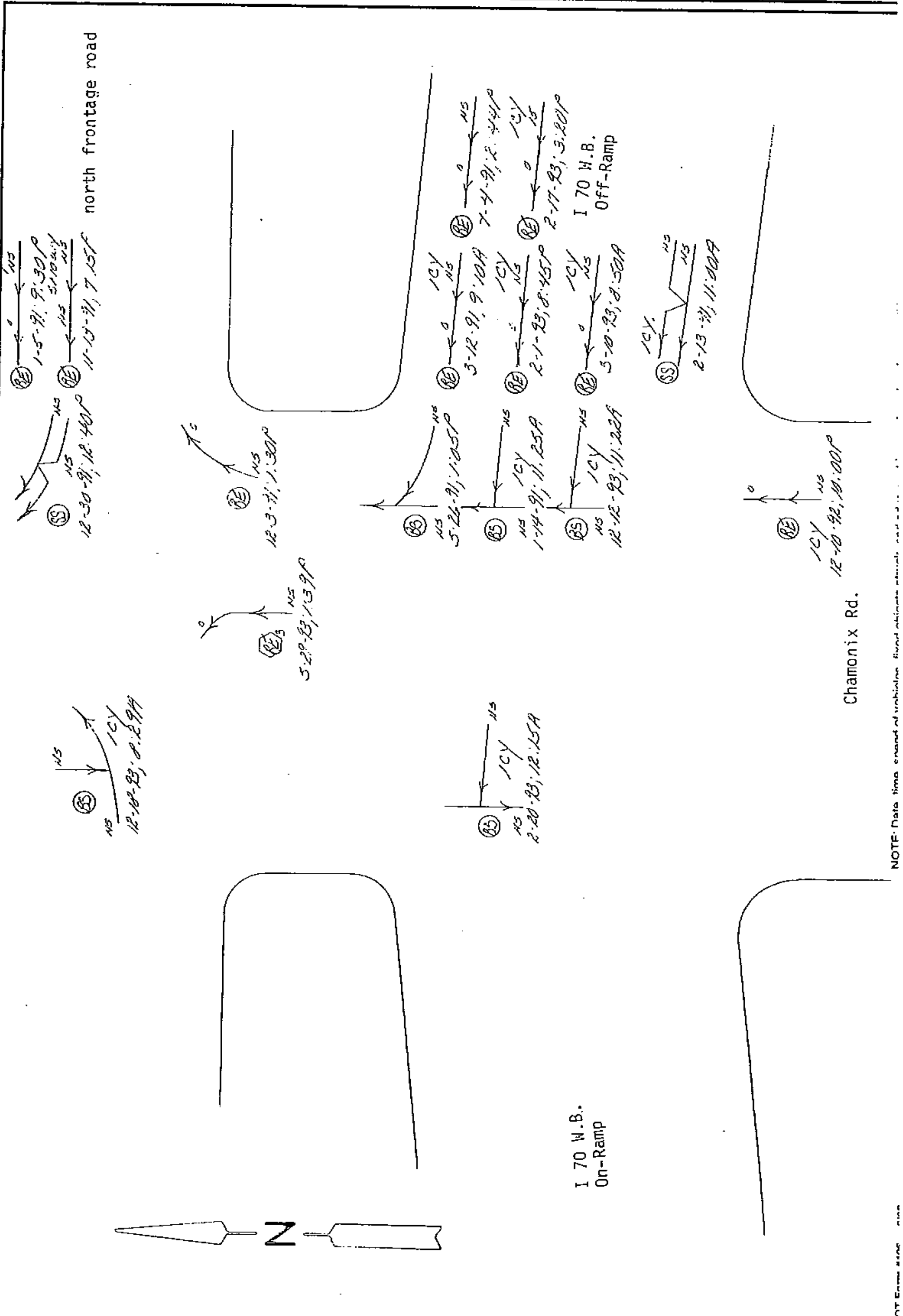
File NO. 880.070.02

Date June 30, 1994

S.H. NO. 70 | District III | Period January 1, 1991 to January 1, 1994 | Sheet 3 of 4

Description SH 70 (I 70) Westbound Ramps and north frontage road at the Intersections with Chamonix Rd. in Vail

Milepoint 173.32 to



APPENDIX D
Understanding Rodel

UNDERSTANDING RODEL

by Leif Ourston, P.E.
Leif Ourston & Associates
Santa Barbara, California

August 25, 1994

ABSTRACT

This report explains Rodel, a computer application that predicts the traffic performance of modern roundabouts. Rodel estimates delay, queue length, and capacity as functions of roundabout geometry and flows. It was used to design Vail's proposed modern roundabout interchanges.

PHILOSOPHY BEHIND RODEL

Rodel was developed by Barry Crown of the Staffordshire County Council in England. It applies research by the United Kingdom's Transport Research Laboratory, which licenses its use. Rodel is faster and easier to use than a widely used program by the British Transport Research Laboratory, ARCADY. Insofar as the two programs overlap, their output is identical.

Rodel works like a spreadsheet in which the designer answers what-if questions by changing one of the input parameters and running the program again. Because Rodel is fast and easy to use, the designer is likely to continue altering his design until a nearly optimal design is achieved.

Rodel permits the designer to select the confidence level of his estimates of traffic performance. A confidence level of 50 percent is implicit in other traffic performance programs, like ARCADY or TRANSYT. Rodel's author recommends using a confidence level of 85 to 95 percent. This allows for inaccuracies in both the input design flows and the output capacity estimate. Often a small increase in roundabout entry width or flare length will greatly increase the probability that the roundabout will perform well at a high confidence level.

The Long Beach roundabout in California was designed using ARCADY before Rodel became available. ARCADY's delay predictions are equal to those of Rodel when Rodel is set to the 50-percent confidence level. Delay predictions at the Long Beach roundabout (the busiest modern American roundabout) compare with actual observed delays as follows:

	AVERAGE STOPPED DELAY (SECONDS PER VEHICLE) PREDICTED	OBSERVED
A.M. Peak Hour	2.2	2.7
P.M. Peak Hour	2.4	3.4

The difference between estimated and observed delay was 0.5 second per vehicle in the morning peak hour and 1.0 second per vehicle in the afternoon peak hour. Because of the close correlation, it is believed that Rodel's estimates of delay may be close to the actual delay that will be observed at modern roundabouts in Vail.

RESEARCH STUDIES

Capacity estimates of Rodel are based on research reported in Kimber, R.M, *The Traffic Capacity of Roundabouts, TRRL Laboratory Report 942*, 1980. Regression equations were developed from data taken at 86 roundabouts on public roads and 35 geometric variations on the TRRL study track. The capacity of each entry to a roundabout (Q_e) was found to be a function of one flow variable, circulating flow, and six geometric parameters. The definitions of symbols are given below.

PARAMETER	SYMBOL
Capacity = maximum entering flow, pcu/h	Q_e
Circulating flow, pcu/h	Q_c
Entry width, m	e
Approach half-width, m	v
Length of flare, m	l'
Inscribed circle diameter, m	D
Entry angle, degrees	ϕ
Entry radius, m	r

Capacity is estimated using the following six regression equations.

PARAMETER	EQUATION
Sharpness of flare	$S = 1.6(e-v)/l'$
Entry width parameter	$x_2 = v+(e-v)/(1+2S)$
Function of D	$t_D = 1+0.5/(1+\exp((D-60)/10))$
Adjustment factor, cap. curve	$k = 1-0.00347(\phi-30)-0.978((1/r)-0.5)$
Slope of capacity curve	$f_c = 0.210t_D(1+0.2x_2)$
Y-intercept, pcu/min	$F = 303x_2$

The best predictive equations of capacity were:

$Q_e = k(F-f_cQ_c)$ when $f_cQ_c <= F$, and
$Q_e = 0$ when $f_cQ_c > F$.

Queues and delays are estimated by use of time-dependent queuing theory. This is reported in Kimber, R.M. and Erica M. Hollis, *Traffic Queues and Delays at Road Junctions, TRRL Laboratory Report 909*, 1979. Queue lengths are estimated in a series of small consecutive time intervals. Traffic demand and capacity are assumed to vary from interval to interval.

INTERPRETING RODEL'S PRINTOUTS

Rodel prints out traffic performance given on a main screen, which has the following twelve fields.

1. TITLE

In the title section of the main screen are the date, written the British way, day:month:year, the name of the roundabout, and the number of the computer run. This last number corresponds to the number given in subsequent statistics screens.

2. GEOMETRY
The user inputs seven geometric parameters. Distances are in meters.

E	Entry width.
L'	Length of flare between V and E.
V	Upstream roadway width before flaring begins.
RAD	Curb return radius.
PHI	Angle between entering traffic and circulating traffic.
DIA	Inscribed circle diameter of the roundabout.
GRAD SEP	Grade separated, 0 or 1? The user inputs a one in this field if the roundabout is very large, as at huge two-bridge British grade separated roundabouts that run over or under the freeway at some interchanges.

3. TIME
The user inputs the following seven parameters which set the periods over which traffic performance estimates are made. Times are in minutes.

TIME PERIOD	The total period to be modeled.
TIME SLICE	Equal pieces of the time period during which capacity and demand flow remain constant. Capacity and flow may change from slice to slice but not within each slice.
RESULTS PERIOD	The period over which results are computed. If the time period is 90 minutes and the results period is from minute 15 to minute 75, then results for the middle 60 minutes are given.
TIME COST	The value of driver's time in British pence per minute.
FLOW PERIOD	The period over which the user inputs turning flows in field 5, explained below. If a 15 and 75 are given, the user inputs flows for the middle 60 minutes.
FLOW TYPE	Flows of field 5 may be entered in passenger car units (pcu's) or vehicles. A truck equals one vehicle or two pcu's.
FLOW PEAK	The peak hour being analyzed: a.m., off peak, or p.m.

4. LEG NAME
The user inputs an abbreviation of the name of each leg of the roundabout. The leg names are in the order of the direction that traffic flows around the roundabout.

5. PCU FACTOR
This is the number of vehicles having more than four wheels divided by the total number of vehicles.

6. TURNING FLOWS
For each leg, the user enters the number of vehicles exiting at the first exit, the second exit, and so on up to the final flow, which is the number of U-turns exiting at the entry leg.

7. FLOW FACTOR (FLOF)
The input flows are multiplied by this factor. With this factor the user can perform a sensitivity analysis to see what would happen if flows were to increase.

8. CONFIDENCE LEVEL (CL)
Queues and delays are predicted at the input confidence level. If 85 is entered, we are 85 percent confident that the queues and delays will not be greater than predicted.

9. FLOW RATIOS
To allow for peaking of traffic within the peak period, the turning flows are shaped into a flow profile. If the time period is 90 minutes and flow times are set at minute numbers 15 and 75, then Rodel shapes the flow profile into three rectangular steps: a beginning 15 minute step, a middle 60 minute step, and a final 15 minute step, the flow being constant within each step. If the user inputs flow ratios of 0.75, 1.125, and 0.75, then Rodel models the flow profile so that flows of the first and third step are 0.75 times the average input flows, and flows of the middle step are 1.125 times the average input flows.

10. FLOW TIMES
The user inputs the flow times that are used with the flow ratios to produce the flow profile from the turning flows.

11. TRAFFIC PERFORMANCE
Rodel outputs the traffic performance of each leg in this field, as follows.

FLOW	Entry flow, vehicles per results period.
CAPACITY	Capacity, vehicles per results period.
AVE DELAY	Average delay, minutes per vehicle over results period.
MAX DELAY	Maximum delay, minutes per vehicle over results period.
AVE QUEUE	Average vehicles in queue over results period.
MAX QUEUE	Maximum vehicles in queue over results period.

12. TOTAL DELAYS AND COSTS
Rodel outputs the total vehicle delay in hours over the results period. It gives the cost of this delay in British pounds stirling.

APPENDIX E

Roundabout Levels of Service

ROUNDABOUT LEVELS OF SERVICE

11-21-95

Leif Ourston & Associates

WEST VAIL NORTH
A.M. PEAK HOUR

100% OF BASE FLOWS

		LEG 1	LEG 2	LEG 3	LEG 4	LEG 5	LEG 6	WHOLE ROUNDABOUT
INPUT FROM RODEL OR ARCADY								
FLOW	veh/hr	124	96	0	680	122	424	1,446
AVE DELAY	min/veh	0.06	0.05	0.00	0.04	0.04	0.04	
OUTPUT								
AVE DELAY	sec/veh	3.6	3.0	0.0	2.4	2.4	2.4	
DELAY	sec/hr	446	288	0	1,632	293	1,018	3,677

AVE DELAY, sec/veh	2.5
LEVEL OF SERVICE	A

246% OF BASE FLOWS

		LEG 1	LEG 2	LEG 3	LEG 4	LEG 5	LEG 6	WHOLE ROUNDABOUT
INPUT FROM RODEL OR ARCADY								
FLOW	veh/hr	305	236	0	1,673	299	1,044	3,557
AVE DELAY	min/veh	0.49	0.15	0.00	0.15	0.13	0.20	
OUTPUT								
AVE DELAY	sec/veh	29.4	9.0		9.0	7.8	12.0	
DELAY	sec/hr	8,967	2,124		15,057	2,332	12,528	41,008

AVE DELAY, sec/veh	11.5
LEVEL OF SERVICE	B

```
*****************************************************************************
*                                                                           *
*  21:11:95            150' N & S 11.  WEST VAIL NORTH.                81  *
*                                                                           *
*****************************************************************************
*                                                 *                         *
* E    (m)   5.18  8.53  8.53  8.56  8.53  8.53   * TIME PERIOD    min    90  *
* L'   (m)  29.79 28.53  0.00  7.36 35.07 33.70   * TIME SLICE     min    15  *
* V    (m)   4.57  3.96  5.79  7.32  5.79  4.27   * RESULTS PERIOD min  15 75  *
* RAD  (m)  19.81 24.38 24.38 30.48 18.90 24.38   * TIME COST    p/min   7.79  *
* PHI  (d)   9.5  40.5   0.0  17.0  40.5  20.0    * FLOW PERIOD    min  15 75  *
* DIA  (m)  45.72 45.72 45.72 45.72 45.72 45.72   * FLOW TYPE  pcu/veh    VEH  *
* GRAD SEP     0     0     0     0     0     0    * FLOW PEAK am/op/pm    AM  *
*                                                 *                         *
*****************************************************************************
* LEG NAME *PCU *FLOWS (1st exit 2nd etc...U)*FLOF*CL*  FLOW RATIO   *FLOW TIME*
*          *    *     -                       *    * *               *         *
*CHAMONI SB*1.02*   4   39   46    0   22   0 *1.00*85*0.75 1.125 0.75*15 45 75 *
*N FR RD EB*1.02*   0   38    0   37   11   0 *1.00*85*0.75 1.125 0.75*15 45 75 *
*ON RAMP WB*1.02*   0    0    0    0    0   0 *1.00*85*0.75 1.125 0.75*15 45 75 *
*CHAMONI NB*1.02*   0  406   30    6  167   0 *1.00*85*0.75 1.125 0.75*15 45 75 *
*OFFRAMP WB*1.02*   0   30   29    0   50   0 *1.00*85*0.75 1.125 0.75*15 45 75 *
*N FR RD WB*1.02*  18   22   91  249    0   0 *1.00*85*0.75 1.125 0.75*15 45 75 *
*          *    *                             *    * *               *         *
*****************************************************************************
*                                                         *                 *
* FLOW       veh     124     96      0    680    122    424 *  TOTAL DELAYS   *
* CAPACITY   veh    1057   1331   1375   2207   1519   1758 *                 *
* AVE DELAY  mins   0.06   0.05   0.00   0.04   0.04   0.04 *       1 hrs     *
* MAX DELAY  mins   0.08   0.06   0.00   0.05   0.05   0.06 *                 *
* AVE QUEUE   veh      0      0      0      0      0      0 *       5 pounds *
* MAX QUEUE   veh      0      0      0      1      0      0 *                 *
*                                                         *                 *
*****************************************************************************
```

```
*****************************************************************************
*                                                                           *
*  21:11:95            150' N & S 11.  WEST VAIL NORTH.                80  *
*                                                                           *
*****************************************************************************
*                                                *                          *
* E    (m)   5.18  8.53  8.53  8.56  8.53  8.53  * TIME PERIOD    min    90  *
* L'   (m)  29.79 28.53  0.00  7.36 35.07 33.70  * TIME SLICE     min    15  *
* V    (m)   4.57  3.96  5.79  7.32  5.79  4.27  * RESULTS PERIOD min  15 75 *
* RAD  (m)  19.81 24.38 24.38 30.48 18.90 24.38  * TIME COST    p/min   7.79 *
* PHI  (d)   9.5  40.5   0.0  17.0  40.5  20.0   * FLOW PERIOD    min  15 75 *
* DIA  (m)  45.72 45.72 45.72 45.72 45.72 45.72  * FLOW TYPE  pcu/veh    VEH *
* GRAD SEP    0     0     0     0     0     0    * FLOW PEAK am/op/pm     AM *
*                                                *                          *
*****************************************************************************
* LEG NAME *PCU *FLOWS (1st exit 2nd etc...U)*FLOF*CL*  FLOW RATIO   *FLOW TIME*
*          *    *                            *    *  *               *         *
*CHAMONI SB*1.02*   4   39   46    0   22   0 *2.46*85*0.75 1.125 0.75*15 45 75 *
*N FR RD EB*1.02*   0   38    0   37   11   0 *2.46*85*0.75 1.125 0.75*15 45 75 *
*ON RAMP WB*1.02*   0    0    0    0    0   0 *2.46*85*0.75 1.125 0.75*15 45 75 *
*CHAMONI NB*1.02*   0  406   30    6  167   0 *2.46*85*0.75 1.125 0.75*15 45 75 *
*OFFRAMP WB*1.02*   0   30   29    0   50   0 *2.46*85*0.75 1.125 0.75*15 45 75 *
*N FR RD WB*1.02*  18   22   91  249    0   0 *2.46*85*0.75 1.125 0.75*15 45 75 *
*          *    *                            *    *  *               *         *
*****************************************************************************
*                                                          *                *
* FLOW        veh     305    236      0   1673    299   1044 *  TOTAL DELAYS  *
* CAPACITY    veh     491    675    914   2124    801   1406 *                *
* AVE DELAY  mins    0.49   0.15   0.00   0.15   0.13   0.20 *      11 hrs    *
* MAX DELAY  mins    0.96   0.23   0.00   0.26   0.21   0.34 *                *
* AVE QUEUE   veh       3      1      0      4      1      4 *      53 pounds *
* MAX QUEUE   veh       5      1      0      7      1      5 *                *
*                                                          *                *
*****************************************************************************
```

ROUNDABOUT LEVELS OF SERVICE

11-21-95

Leif Ourston & Associates

WEST VAIL NORTH
P.M. PEAK HOUR

100% OF BASE FLOWS

		LEG 1	LEG 2	LEG 3	LEG 4	LEG 5	LEG 6	WHOLE ROUNDABOUT
INPUT FROM RODEL OR ARCADY								
FLOW	veh/hr	164	95	0	1,259	52	796	2,366
AVE DELAY	min/veh	0.09	0.06	0.00	0.06	0.05	0.07	
OUTPUT								
AVE DELAY	sec/veh	5.4	3.6	0.0	3.6	3.0	4.2	
DELAY	sec/hr	886	342	0	4,532	156	3,343	9,259

AVE DELAY, sec/veh	3.9
LEVEL OF SERVICE	A

156% OF BASE FLOWS

		LEG 1	LEG 2	LEG 3	LEG 4	LEG 5	LEG 6	WHOLE ROUNDABOUT
INPUT FROM RODEL OR ARCADY								
FLOW	veh/hr	256	148	0	1,964	82	1,242	3,692
AVE DELAY	min/veh	0.45	0.13	0.00	0.47	0.11	0.30	
OUTPUT								
AVE DELAY	sec/veh	27.0	7.8	0.0	28.2	6.6	18.0	
DELAY	sec/hr	6,912	1,154	0	55,385	541	22,356	86,348

AVE DELAY, sec/veh	23.4
LEVEL OF SERVICE	C

```
****************************************************************************
*                                                                          *
*  21:11:95            150' N & S 11.  WEST VAIL NORTH.               83  *
*                                                                          *
****************************************************************************
*                                               *                          *
* E    (m)   5.18  8.53  8.53  8.56  8.53  8.53  * TIME PERIOD    min    90  *
* L'   (m)  29.79 28.53  0.00  7.36 35.07 33.70  * TIME SLICE     min    15  *
* V    (m)   4.57  3.96  5.79  7.32  5.79  4.27  * RESULTS PERIOD min  15 75  *
* RAD  (m)  19.81 24.38 24.38 30.48 18.90 24.38  * TIME COST    p/min   7.79  *
* PHI  (d)   9.5  40.5   0.0  17.0  40.5  20.0   * FLOW PERIOD    min  15 75  *
* DIA  (m)  45.72 45.72 45.72 45.72 45.72 45.72  * FLOW TYPE  pcu/veh    VEH  *
* GRAD SEP    0     0     0     0     0     0    * FLOW PEAK am/op/pm     PM  *
*                                               *                          *
****************************************************************************
* LEG NAME *PCU *FLOWS (1st exit 2nd etc...U)*FLOF*CL*  FLOW RATIO   *FLOW TIME*
*          *    *                            *    *  *              *         *
*CHAMONI SB*1.02*   2   62   52    0   31    0 *1.00*85*0.75 1.125 0.75*15 45 75 *
*N FR RD EB*1.02*   0   45    0   28   12    0 *1.00*85*0.75 1.125 0.75*15 45 75 *
*ON RAMP WB*1.02*   0    0    0    0    0    0 *1.00*85*0.75 1.125 0.75*15 45 75 *
*CHAMONI NB*1.02*   0  762   72   36  257    0 *1.00*85*0.75 1.125 0.75*15 45 75 *
*OFFRAMP WB*1.02*   0   13    6    2   26    0 *1.00*85*0.75 1.125 0.75*15 45 75 *
*N FR RD WB*1.02*  22   15  357  319    0    0 *1.00*85*0.75 1.125 0.75*15 45 75 *
*          *    *                            *    *  *              *         *
****************************************************************************
*                                                          *               *
* FLOW        veh     164     95      0   1259     52    796 *  TOTAL DELAYS  *
* CAPACITY    veh     802   1032   1333   2206   1143   1683 *                *
* AVE DELAY  mins    0.09   0.06   0.00   0.06   0.05   0.07 *      3 hrs     *
* MAX DELAY  mins    0.13   0.09   0.00   0.09   0.07   0.09 *                *
* AVE QUEUE   veh       0      0      0      1      0      1 *     12 pounds  *
* MAX QUEUE   veh       0      0      0      2      0      1 *                *
*                                                          *               *
****************************************************************************
```

```
******************************************************************************
*                                                                            *
*  21:11:95            150' N & S 11.  WEST VAIL NORTH.                 82  *
*                                                                            *
******************************************************************************
*                                                 *                          *
* E     (m)   5.18  8.53  8.53  8.56  8.53  8.53  * TIME PERIOD    min   90  *
* L'    (m)  29.79 28.53  0.00  7.36 35.07 33.70  * TIME SLICE     min   15  *
* V     (m)   4.57  3.96  5.79  7.32  5.79  4.27  * RESULTS PERIOD min 15 75 *
* RAD   (m)  19.81 24.38 24.38 30.48 18.90 24.38  * TIME COST    p/min  7.79 *
* PHI   (d)   9.5  40.5   0.0  17.0  40.5  20.0   * FLOW PERIOD    min 15 75 *
* DIA   (m)  45.72 45.72 45.72 45.72 45.72 45.72  * FLOW TYPE  pcu/veh   VEH *
* GRAD SEP     0     0     0     0     0     0    * FLOW PEAK am/op/pm    PM *
*                                                 *                          *
******************************************************************************
* LEG NAME *PCU *FLOWS (1st exit 2nd etc...U)*FLOF*CL*  FLOW RATIO   *FLOW TIME*
*          *    *                            *    *  *               *         *
*CHAMONI SB*1.02*   2   62   52    0   31    0 *1.56*85*0.75 1.125 0.75*15 45 75 *
*N FR RD EB*1.02*   0   45    0   28   12    0 *1.56*85*0.75 1.125 0.75*15 45 75 *
*ON RAMP WB*1.02*   0    0    0    0    0    0 *1.56*85*0.75 1.125 0.75*15 45 75 *
*CHAMONI NB*1.02*   0  762   72   36  257    0 *1.56*85*0.75 1.125 0.75*15 45 75 *
*OFFRAMP WB*1.02*   0   13    6    2   26    0 *1.56*85*0.75 1.125 0.75*15 45 75 *
*N FR RD WB*1.02*  22   15  357  319    0    0 *1.56*85*0.75 1.125 0.75*15 45 75 *
*          *    *                            *    *  *               *         *
******************************************************************************
*                                                         *                  *
* FLOW        veh     256    148      0   1964     82   1242 *  TOTAL DELAYS   *
* CAPACITY    veh     443    614   1133   2174    658   1506 *                 *
* AVE DELAY  mins    0.45   0.13   0.00   0.47   0.11   0.30 *     24 hrs      *
* MAX DELAY  mins    0.88   0.21   0.00   1.02   0.16   0.58 *                 *
* AVE QUEUE   veh       2      0      0     16      0      6 *     113 pounds  *
* MAX QUEUE   veh       4      0      0     32      0     11 *                 *
*                                                         *                  *
******************************************************************************
```

ROUNDABOUT LEVELS OF SERVICE

11-21-95

Leif Ourston & Associates

WEST VAIL SOUTH
A.M. PEAK HOUR

100% OF BASE FLOWS

		LEG 1	LEG 2	LEG 3	LEG 4	LEG 5	LEG 6	WHOLE ROUNDABOUT
INPUT FROM RODEL OR ARCADY								
FLOW	veh/hr	428	648	171	46	342	0	1,635
AVE DELAY	min/veh	0.07	0.05	0.07	0.09	0.04	0.00	
OUTPUT								
AVE DELAY	sec/veh	4.2	3.0	4.2	5.4	2.4	0.0	
DELAY	sec/hr	1,798	1,944	718	248	821	0	5,529

AVE DELAY, sec/veh	3.4
LEVEL OF SERVICE	A

167% OF BASE FLOWS

		LEG 1	LEG 2	LEG 3	LEG 4	LEG 5	LEG 6	WHOLE ROUNDABOUT
INPUT FROM RODEL OR ARCADY								
FLOW	veh/hr	714	1,082	285	76	571	0	2,728
AVE DELAY	min/veh	0.11	0.11	0.29	0.50	0.05	0.00	
OUTPUT								
AVE DELAY	sec/veh	6.6	6.6	17.4	30.0	3.0		
DELAY	sec/hr	4,712	7,141	4,959	2,280	1,713		20,806

AVE DELAY, sec/veh	7.6
LEVEL OF SERVICE	B

```
*******************************************************************************
*                                                                             *
*  21:11:95           150' N & S 12.  WEST VAIL SOUTH.                    87  *
*                                                                             *
*******************************************************************************
*                                                   *                         *
* E     (m)   5.55  9.14  7.08  4.88  9.75  9.14    * TIME PERIOD     min    90  *
* L'    (m)   5.00 33.58 14.05  0.00 87.10 30.48    * TIME SLICE      min    15  *
* V     (m)   3.66  6.40  3.66  4.88  4.27  6.10    * RESULTS PERIOD min  15 75  *
* RAD   (m)  19.81 13.72 42.37 10.18 30.48 13.72    * TIME COST     p/min  7.79  *
* PHI   (d)  13.5  36.5  13.0   5.5  40.5   0.0     * FLOW PERIOD     min  15 75  *
* DIA   (m)  45.72 45.72 45.72 45.72 48.16 45.72    * FLOW TYPE  pcu/veh    VEH  *
* GRAD SEP     0     0     0     0     0     0    * FLOW PEAK am/op/pm     AM  *
*                                                   *                         *
*******************************************************************************
* LEG NAME *PCU *FLOWS (1st exit 2nd etc...U)*FLOF*CL*  FLOW RATIO   *FLOW TIME*
*          *    *                            *    *  *               *         *
*CHAMONI SB*1.02*   0   31    4  236  112   0 *1.00*85*0.75 1.125 0.75*15 45 75 *
*OFFRAMP EB*1.02*   0    7  335    0  238   0 *1.00*85*0.75 1.125 0.75*15 45 75 *
*S FR RD EB*1.02*   0   74   10   69    0   0 *1.00*85*0.75 1.125 0.75*15 45 75 *
*CHAMONI NB*1.02*  24    4   13    0    0   0 *1.00*85*0.75 1.125 0.75*15 45 75 *
*S FR RD WB*1.02*   0  289    0   16    1   0 *1.00*85*0.75 1.125 0.75*15 45 75 *
*ON RAMP EB*1.02*   0    0    0    0    0   0 *1.00*85*0.75 1.125 0.75*15 45 75 *
*          *    *                            *    *  *               *         *
*******************************************************************************
*                                                          *                  *
* FLOW        veh      428    648    171     46    342      0 *  TOTAL DELAYS   *
* CAPACITY    veh     1242   1846    966    689   1925   1857 *                  *
* AVE DELAY  mins     0.07   0.05   0.07   0.09   0.04   0.00 *        2 hrs     *
* MAX DELAY  mins     0.09   0.07   0.10   0.13   0.05   0.00 *                  *
* AVE QUEUE   veh        1      1      0      0      0      0 *        7 pounds *
* MAX QUEUE   veh        1      1      0      0      0      0 *                  *
*                                                          *                  *
*******************************************************************************
```

```
******************************************************************************
*                                                                            *
*  21:11:95            150' N & S 12.  WEST VAIL SOUTH.                  86  *
*                                                                            *
******************************************************************************
*                                                  *                         *
* E    (m)    5.55  9.14  7.08  4.88  9.75  9.14   * TIME PERIOD    min    90  *
* L'   (m)    5.00 33.58 14.05  0.00 87.10 30.48   * TIME SLICE     min    15  *
* V    (m)    3.66  6.40  3.66  4.88  4.27  6.10   * RESULTS PERIOD min  15 75  *
* RAD  (m)   19.81 13.72 42.37 10.18 30.48 13.72   * TIME COST    p/min   7.79  *
* PHI  (d)   13.5  36.5  13.0   5.5  40.5   0.0    * FLOW PERIOD    min  15 75  *
* DIA  (m)   45.72 45.72 45.72 45.72 48.16 45.72   * FLOW TYPE  pcu/veh    VEH  *
* GRAD SEP     0     0     0     0     0     0     * FLOW PEAK am/op/pm     AM  *
*                                                  *                         *
******************************************************************************
* LEG NAME *PCU *FLOWS (1st exit 2nd etc...U)*FLOF*CL*  FLOW RATIO   *FLOW TIME*
*         *    *                            *    *  *               *          *
*CHAMONI SB*1.02*   0   31    4  236  112   0 *1.67*85*0.75 1.125 0.75*15 45 75 *
*OFFRAMP EB*1.02*   0    7  335    0  238   0 *1.67*85*0.75 1.125 0.75*15 45 75 *
*S FR RD EB*1.02*   0   74   10   69    0   0 *1.67*85*0.75 1.125 0.75*15 45 75 *
*CHAMONI NB*1.02*  24    4   13    0    0   0 *1.67*85*0.75 1.125 0.75*15 45 75 *
*S FR RD WB*1.02*   0  289    0   16    1   0 *1.67*85*0.75 1.125 0.75*15 45 75 *
*ON RAMP EB*1.02*   0    0    0    0    0   0 *1.67*85*0.75 1.125 0.75*15 45 75 *
*         *    *                            *    *  *               *          *
******************************************************************************
*                                                       *                    *
* FLOW       veh     714   1082    285     76    571      0 *  TOTAL DELAYS    *
* CAPACITY   veh    1235   1645    549    260   1693   1504 *                  *
* AVE DELAY  mins   0.11   0.11   0.29   0.50   0.05   0.00 *        6 hrs     *
* MAX DELAY  mins   0.16   0.18   0.52   0.95   0.07   0.00 *                  *
* AVE QUEUE   veh      1      2      1      1      1      0 *      28 pounds   *
* MAX QUEUE   veh      2      3      2      1      1      0 *                  *
*                                                       *                    *
******************************************************************************
```

ROUNDABOUT LEVELS OF SERVICE

11-21-95

Leif Ourston & Associates

WEST VAIL SOUTH
P.M. PEAK HOUR

100% OF BASE FLOWS

		LEG 1	LEG 2	LEG 3	LEG 4	LEG 5	LEG 6	WHOLE ROUNDABOUT
INPUT FROM RODEL OR ARCADY								
FLOW	veh/hr	494	573	130	56	868	0	2,121
AVE DELAY	min/veh	0.08	0.05	0.07	0.09	0.06	0.00	
OUTPUT								
AVE DELAY	sec/veh	4.8	3.0	4.2	5.4	3.6	0.0	
DELAY	sec/hr	2,371	1,719	546	302	3,125	0	8,063
					AVE DELAY, sec/veh			3.8
					LEVEL OF SERVICE			A

156% OF BASE FLOWS

		LEG 1	LEG 2	LEG 3	LEG 4	LEG 5	LEG 6	WHOLE ROUNDABOUT
INPUT FROM RODEL OR ARCADY								
FLOW	veh/hr	770	894	202	87	1,354	0	3,307
AVE DELAY	min/veh	0.14	0.09	0.15	0.22	0.49	0.00	
OUTPUT								
AVE DELAY	sec/veh	8.4	5.4	9.0	13.2	29.4		
DELAY	sec/hr	6,468	4,828	1,818	1,148	39,808		54,070
					AVE DELAY, sec/veh			16.4
					LEVEL OF SERVICE			C

```
*****************************************************************************
*                                                                           *
*  21:11:95            150' N & S 12.  WEST VAIL SOUTH.                89  *
*                                                                           *
*****************************************************************************
*                                                  *                        *
* E    (m)   5.55  9.14  7.08  4.88  9.75  9.14   * TIME PERIOD    min   90  *
* L'   (m)   5.00 33.58 14.05  0.00 87.10 30.48   * TIME SLICE     min   15  *
* V    (m)   3.66  6.40  3.66  4.88  4.27  6.10   * RESULTS PERIOD min 15 75 *
* RAD  (m)  19.81 13.72 42.37 10.18 30.48 13.72   * TIME COST    p/min  7.79 *
* PHI  (d)  13.5  36.5  13.0   5.5  40.5   0.0    * FLOW PERIOD    min 15 75 *
* DIA  (m)  45.72 45.72 45.72 45.72 48.16 45.72   * FLOW TYPE  pcu/veh   VEH *
* GRAD SEP     0     0     0     0     0     0    * FLOW PEAK am/op/pm    PM *
*                                                  *                        *
*****************************************************************************
* LEG NAME *PCU *FLOWS (1st exit 2nd etc...U)*FLOF*CL*  FLOW RATIO   *FLOW TIME*
*          *    *                             *    *  *              *         *
*CHAMONI SB*1.02*   0   44    8  248 142    0 *1.00*85*0.75 1.125 0.75*15 45 75 *
*OFFRAMP EB*1.02*   0   11  193    4 305    0 *1.00*85*0.75 1.125 0.75*15 45 75 *
*S FR RD EB*1.02*   2   27    4   83   0    0 *1.00*85*0.75 1.125 0.75*15 45 75 *
*CHAMONI NB*1.02*  17    5   28    0   0    0 *1.00*85*0.75 1.125 0.75*15 45 75 *
*S FR RD WB*1.02*   0  711    0   48  18    0 *1.00*85*0.75 1.125 0.75*15 45 75 *
*ON RAMP EB*1.02*   0    0    0    0   0    0 *1.00*85*0.75 1.125 0.75*15 45 75 *
*          *    *                             *    *  *              *         *
*****************************************************************************
*                                                              *            *
* FLOW        veh      494    573    130     56    868      0 *  TOTAL DELAYS *
* CAPACITY    veh     1213   1765    969    729   1828   1379 *            *
* AVE DELAY  mins     0.08   0.05   0.07   0.09   0.06   0.00 *      2 hrs *
* MAX DELAY  mins     0.11   0.07   0.10   0.12   0.09   0.00 *            *
* AVE QUEUE   veh        1      0      0      0      1      0 *   11 pounds *
* MAX QUEUE   veh        1      1      0      0      1      0 *            *
*                                                              *            *
*****************************************************************************
```

```
*****************************************************************************
*                                                                           *
*  21:11:95            150' N & S 12.  WEST VAIL SOUTH.                88  *
*                                                                           *
*****************************************************************************
*                                                 *                         *
* E     (m)   5.55  9.14  7.08  4.88  9.75  9.14   * TIME PERIOD     min     90  *
* L'    (m)   5.00 33.58 14.05  0.00 87.10 30.48   * TIME SLICE      min     15  *
* V     (m)   3.66  6.40  3.66  4.88  4.27  6.10   * RESULTS PERIOD min  15 75  *
* RAD   (m)  19.81 13.72 42.37 10.18 30.48 13.72   * TIME COST    p/min   7.79  *
* PHI   (d)  13.5  36.5  13.0   5.5  40.5   0.0    * FLOW PERIOD     min  15 75  *
* DIA   (m)  45.72 45.72 45.72 45.72 48.16 45.72   * FLOW TYPE  pcu/veh    VEH  *
* GRAD SEP     0     0     0     0     0     0     * FLOW PEAK am/op/pm     PM  *
*                                                 *                         *
*****************************************************************************
* LEG NAME *PCU *FLOWS (1st exit 2nd etc...U)*FLOF*CL*  FLOW RATIO   *FLOW TIME*
*          *    *                            *    *  *               *         *
*CHAMONI SB*1.02*   0   44    8  248 142    0 *1.56*85*0.75 1.125 0.75*15 45 75 *
*OFFRAMP EB*1.02*   0   11  193    4 305    0 *1.56*85*0.75 1.125 0.75*15 45 75 *
*S FR RD EB*1.02*   2   27    4   83   0    0 *1.56*85*0.75 1.125 0.75*15 45 75 *
*CHAMONI NB*1.02*  17    5   28    0   0    0 *1.56*85*0.75 1.125 0.75*15 45 75 *
*S FR RD WB*1.02*   0  711    0   48  18    0 *1.56*85*0.75 1.125 0.75*15 45 75 *
*ON RAMP EB*1.02*   0    0    0    0   0    0 *1.56*85*0.75 1.125 0.75*15 45 75 *
*          *    *                            *    *  *               *         *
*****************************************************************************
*                                                       *                   *
* FLOW        veh      770    894    202     87    1354      0 *  TOTAL DELAYS    *
* CAPACITY    veh     1192   1551    622    394    1580    818 *                  *
* AVE DELAY  mins     0.14   0.09   0.15   0.22    0.49   0.00 *       15 hrs     *
* MAX DELAY  mins     0.21   0.14   0.24   0.35    1.04   0.00 *                  *
* AVE QUEUE   veh        2      1      1      0      11      0 *       70 pounds *
* MAX QUEUE   veh        2      2      1      0      22      0 *                  *
*                                                       *                   *
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