

# BELL ROAD PROJECT DRAINAGE STUDY

## EXECUTIVE SUMMARY

FOR

MARICOPA COUNTY  
FLOOD CONTROL DISTRICT

*PREPARED BY*

**GREINER ENGINEERING  
SCIENCES, INC.**

**PHOENIX, ARIZONA**

*OCTOBER, 1987*



**Greiner**

## BELL ROAD PROJECT DRAINAGE STUDY

### Executive Summary

A stormwater/floodwater management plan has been developed that will provide a cost-effective method of handling on-site drainage from the expansion of Bell Road and protection for the roadway from off-site runoff for the selected design storm. The improved Bell Road is conceived as a six lane urban arterial street extending twenty-five miles from Grand Avenue to Scottsdale Road. The plan ensures that downstream drainage receiving facilities and the ultimate regional stormwater/floodwater outfalls have adequate capacity to handle the on-site and off-site stormwater flows from the Bell Road Expansion project.

The plan will also provide for future storm drain laterals to be extended north of Bell Road to intercept drainage. Downstream properties will benefit by the reduction of stormwater and floodwater flows. In no instance has the project worsened upstream flood conditions or created new problem drainage areas.

The Bell Road Project Drainage Study has provided the additional benefit of coordinating and integrating nine (9) Area Drainage Master Studies and Stormwater Master Drainage Plans developed for the participating jurisdictions between 1977 and 1986 into one comprehensive plan.

The Executive Summary is organized in the same manner as the comprehensive Bell Road Project Drainage Study report and provides a general overview of the study. For a detailed evaluation of the study tasks relating to the stormwater/floodwater plan development, reference is made to specific Volumes and Sections of the report for consultation.

## Study Objectives

The objective of the study is to develop a stormwater management plan for the expansion of Bell Road from Grand Avenue to Scottsdale Road which includes a cost-effective method of handling on-site drainage, as well as providing flood protection for the roadway. The plan ensures that downstream drainage facilities can handle discharged flows or that new facilities can be provided to an adequate outfall. Upstream properties will not be adversely affected by the construction of the roadway or drainage facilities.

To achieve the objective, the study was divided into the following sequential tasks:

- o Review the existing hydrologic information and data basic to the study and determine which segments of Bell Road have adequate hydrologic information from which to plan drainage facilities.
- o Develop hydrology for the areas without adequate hydrologic information using the HEC-1 Flood Hydrograph Package developed by the United States Army Corps of Engineers. Compute the 2, 5, 10, 50 and 100 year peak runoff rates and volumes for the existing and post-development (future) conditions.
- o Develop a minimum of three alternative stormwater/floodwater management plans.
- o Evaluate, at a study level, each alternative in terms of capital costs, effectiveness, environmental impacts, potential for staged construction, acceptability to municipalities and compatibility with other projects and plans. Prepare a general working matrix for ranked comparison of alternative plans.

- o Present the ranked alternatives in report and oral presentation format to a Review Committee, providing sufficient background and cost information to support the decision process for selection of a preferred alternative plan.
- o Develop the selected system proposed for the drainage master plan, to preliminary plan level, including sizes, slopes, profiles, alignments and locations as appropriate for channels, pipes, trunk mains, culverts and detention or retention basins. Determine the existing and required rights-of-way, and estimate preliminary quantities and costs for each element of the system.
- o Analyze the impact of the design storm(s) on major drainage facilities downstream of Bell Road.
- o Recommend design criteria and objectives to be applied during the implementation of the selected drainage plan.

Five jurisdictions (City of Phoenix, City of Glendale, City of Peoria, Town of Surprise and the Flood Control District of Maricopa County) and the Maricopa County Highway Department actively participated in the study. Representatives of these jurisdictions and the department comprised the Review Committee. The Review Committee was responsible for the review of the technical study findings, selection of the recommended stormwater/floodwater management plan and design criteria appropriate for their jurisdiction.

#### Report Format

The comprehensive Bell Road Project Drainage Study is a collection of documents, reports, analyses and data encompassing the entire study. This information is summarized in the four written reports and associated documentations. Volume I, "Hydrologic Modeling," is a written report documenting the evaluation of existing and ongoing hydrologic studies and flood

control facilities affecting the Bell Road Project Drainage Study, the hydrologic data collections and hydrologic modeling. Volume II is an appendix to Volume I and contains the summary HEC-1 Computer Output for the hydrologic models of existing and post-development conditions. Volume III, "Alternative Stormwater/Floodwater Management Concept Plans," provides a detailed description of the alternative concept plans evaluated. This report includes the evaluation of each alternative in terms of capital costs, effectiveness, environmental impacts, potential for staged construction, acceptability and compatibility with other projects and plans. Volume IV, "Selected Stormwater/Floodwater Management Plan", develops the selected drainage facilities to preliminary plan level including estimated quantities and costs for each element of the system. Plan and profile sheets are included in the report with the sizes, slopes, profiles and alignments of the recommended drainage facilities along Bell Road. Recommended design criteria and objectives to be applied during implementation of the selected drainage plan are also included.

#### Study Drainage Areas

To facilitate the hydrologic investigations and HEC-1 computer modeling, the Bell Road project drainage study watershed was divided into ten drainage areas, the limits of which are shown on Exhibit 1. These areas are briefly described as follows:

Area 1: Bound by Bell Road on the south, Grand Avenue on the west, McMicken Dam Outlet Channel on the north and the west boundary of Sun City on the east. This drainage area is approximately 0.3 square miles.

Area 2: Bound by Bell Road on the south, Agua Fria River to the west, New River on the east and the ridge on the mountain in Section 4, Township 4 North, Range 1 East on the north. This drainage area is approximately 10.2 square miles.

- Area 3: Bound by Bell Road on the south, New River on the west, Skunk Creek to the east and Union Hills Drive to the north. This drainage area is approximately 1.5 square miles.
- Area 4: Bound by Bell Road on the south, Skunk Creek to the west, Beardsley Road on the north and Interstate 17 on the east. This drainage area is approximately 8.0 square miles.
- Area 5: Bound by Bell Road on the south, Interstate 17 on the west, Cave Creek on the east and the ridge line of the Union Hills on the north. This drainage area is approximately 9.0 square miles.
- Area 6: Bound by Bell Road on the south, Cave Creek on the west, East Fork of Cave Creek on the east and just north of Beardsley Road on the north. This drainage area is approximately 4.0 square miles.
- Area 7: East Fork of Cave Creek watershed. This drainage area is approximately 4.8 square miles.
- Area 8: Bound by Bell Road on the south, East Fork of Cave Creek drainage divide on the west and the Central Arizona Project on the north and east. This drainage area is approximately 7.3 square miles.
- Area 9: Skunk Creek watershed. This drainage area is approximately 7.3 square miles.
- Area 10: Cave Creek watershed. This drainage area is approximately 6.9 square miles.

### Evaluation of Existing Data

Existing and on-going hydrologic studies and the hydrology of major flood control, water transport and highway facilities affecting the Bell Road Project Drainage Study were reviewed and evaluated. The purpose of this evaluation was to determine what existing information may be utilized in developing the hydrology for the Bell Road study; thereby ensuring that the results would be compatible with previous or on-going studies by others. Adequacy of hydrologic information was determined by the criteria established by the Maricopa County Flood Control District as outlined in Section IV.C of Volume I.

It was determined that hydrologic modeling will be required of all areas tributary to Bell Road with the exception of Sun City and Sun City West. Refer to Table 1 in Volume I for the summary of results of the evaluations.

### Hydrologic Modeling

The objective of the modeling was to develop the hydrology for the areas within the overall study area where existing hydrologic information was inadequate. Hydrology was performed using the HEC-1 Flood Hydrograph Package. All subareas were identified and the hydrologic characteristics tabulated for each. Peak flows for existing and post-development (future) conditions were calculated for the 24-hour duration storm for the 2-, 5-, 10-, 50-, and 100-year storm events. Post-development conditions are based on adopted community land use master plans and current or pending drainage retention criteria for the appropriate jurisdiction.

Pre-development conditions were modelled to establish a basis for evaluating potential impacts of any proposed stormwater/floodwater management facilities on existing facilities or developments. The results of the analysis of fully-developed (future) watershed conditions were used in the design of the proposed facilities to ensure that stormwater runoff generated by future

development in the upper watershed will be accommodated in the Bell Road drainage facilities. Planned and approved stormwater facilities were incorporated into the above analysis.

For the results of the hydrologic modeling, see Volume I (written report and exhibits) and Volume II (HEC-1 summary results).

### Alternative Plan Development

Separate alternative stormwater/floodwater management concept plans were developed for the 100-year, 24-hour and the 10-year, 24-hour storm event. The alternative concept plans included collection points for on-site drainage of the roadway and conveyance of off-site and on-site drainage to the alternative outfalls. Alternative concepts studied were multiple conveyance systems versus single conveyance systems, use of multiple outfalls versus single outfalls, closed conduits versus open channel, or a combination of both and detention systems.

A minimum of three alternative stormwater/floodwater management systems were evaluated for most of the drainage areas investigated. In general, system alignments were selected to conform to topographic features of the drainage areas. To achieve the design objective of 100 percent interception of off-site runoff at the Bell Road right-of-way, it was often necessary to evaluate trunk storm drains, open channels or detention basins in the upper watershed along the section-line and half-section line streets. These alignments were generally followed because of right-of-way availability, minimal utility conflicts and minimal disruption of residential areas. Also, the general trend for urban development in the study area is based on a grid pattern.

Initially, only drainage systems providing protection to the 100-year storm design level were evaluated. When the preliminary cost estimates were developed, it became apparent to the participating jurisdictions that the costs of drainage systems designed for the 100-year storm level would be

prohibitive. At the request of the participating jurisdictions, Greiner developed order of magnitude costs estimates for selected stormwater/floodwater management systems for the 2-, 5-, 10-, 50-, and 100-year storm events. Using the costs of the 100-year design storm system as a benchmark, the costs would be 19 percent, 37 percent, 53 percent and 84 percent of the 100-year storm system for the 2-, 5-, 10-, and 50-year storms, respectively. On the basis of this order of magnitude comparison, Greiner was directed to develop alternative concept plans for a 10-year design storm as it had done for the 100-year storm event.

A HEC-1 computer model was developed for each alternative and post-development (future) flows were routed through. The types, sizes and locations of drainage facilities were developed from the model results.

Volume III, "Alternate Stormwater/Floodwater Management Concept Plans," documents the procedure for selection and evaluation of the concept plans. Plates 1 through 56 within the above mentioned report are schematics of the 10-year and 100-year alternative concept plans.

### Selected Plan

The City of Glendale and Maricopa County Highway Department selected the 10-year storm as the preferred design level for the Bell Road facilities. The City of Peoria and City of Phoenix requested that the drainage facilities proposed for the segments of Bell Road within their respective jurisdictions be downsized to the 2-year storm design level. The design storm frequencies specified by the City of Glendale and the City of Phoenix will ensure that the design of the Bell Road Project drainage facilities within their jurisdictions are consistent with their adopted stormwater management plans. Facilities within the Town of Surprise will be designed for the 10-year frequency storm.

In addition to incorporating drainage facilities adopted by current storm-water management plans, the selected plan incorporated the drainage facilities for the East Fork of Cave Creek Wash, proposed by others to manage runoff from the 100-year storm event. For each drainage system, a HEC-1 computer model was developed for post-development conditions for the selected design storm frequency.

Structure summaries were prepared which list structure number, structure type, design frequency, design discharge or volume (conduits or basins respectively), slope, channel characteristics and length. Required additional rights-of-way, quantities and costs were also estimated. The selected systems are presented in Plates 1 through 11 in this report and in Volume IV of the comprehensive report. Refer also to Volume IV for plan and profile plans of the facilities along Bell Road.

#### **Analysis of Downstream Impacts**

All of the proposed drainage facilities for Bell Road were evaluated to determine their potential for impacts on existing and future drainage facilities and regional drains (Indian Bend Wash, East Fork of Cave Creek, Greenway Channel, Cave Creek, Arizona Canal Diversion Channel, Skunk Creek, New River and Agua Fria River). It was determined that the downstream receiving drainage facilities have been designed for either the equivalent (2 or 10-year) design storm event or greater storm event. No adverse impacts are anticipated. Refer to Section XII of Volume IV for this analysis.

#### **Design Criteria**

Drainage design criteria for the proposed facilities were developed to assist the Bell Road segment designers.

Current state-of-the-art criteria in use by local, regional and statewide jurisdictions were reviewed. For the recommended drainage criteria, see Appendix A in Volume IV.

### Technical Reference List

The Technical Reference List presented in the back of Volume I provides a detailed index of the technical data developed during the preparation of the Bell Road Project Drainage Study reports. This data base, including magnetic diskettes of the HEC-1 Computer Modeling have been provided to the Flood Control District of Maricopa County for use during the final design phase of the Bell Road project.

### Conclusions

The selected stormwater/floodwater management plan for Bell Road will provide the required number of dry traffic lanes during the design storm event. In addition to protecting the roadway, the selected plan will not adversely affect either upstream properties or downstream receiving drainage facilities.

The selected plan was developed to be compatible with existing and proposed drainage and flood control projects.

In the process of selecting the plan, careful consideration was also given to environmental concerns and acceptability to municipalities and potential for conflict in scheduling of the Bell Road drainage facilities and the outfall facilities proposed by others.

The staging of the Bell Road project drainage improvements with the construction phasing for the Bell Road roadway improvements, as proposed by the Bell Road Project Management Consultant, was also reviewed. Just as it is critical to ensure that downstream outfalls are operational before the Bell Road drainage facilities are completed, it is important that the downstream drainage facilities along Bell Road are completed before the upstream facilities along Bell Road. Utility relocations and the construction of drainage facilities must precede the pavement improvements to ensure the integrity of the final paving work.

Table 1 represents the construction dates for the segments of Bell Road as proposed by the Management Consultant. These dates are broken out by drainage area and location. Comments are provided on potential for conflict between the roadway construction schedules and the downstream to upstream staging of Bell Road drainage facilities.

Costs were developed for facilities associated with construction of the Bell Road expansion. Costs were also developed for proposed facilities upstream and downstream of Bell Road that will be constructed prior to and/or in the future of the system for Bell Road only. Costs include construction, engineering, administration and land acquisition. These facilities were developed, for the most part, by ongoing or adopted drainage master plans or area drainage master studies proposed by others.

Table 2 is a summary of total costs broken out by location (north, south or along Bell Road), adopted drainage master plan or ongoing study and by jurisdictions.

The costs for the Bell Road drainage facilities were also evaluated with respect to the proposed construction schedule. Table 3 presents costs by fiscal year and by jurisdictions for each design segment of Bell Road. This cost breakout will assist the participating jurisdictions in planning their budgets for each year during the project duration. Total project costs by jurisdictions and by fiscal year are also available from the table. Total Bell Road project costs (drainage facilities along Bell Road only) will be approximately \$14.1 million. Costs to the participating jurisdictions will be as follows:

Town of Surprise	\$ 0.1 million
City of Peoria	\$ 0.6 million
City of Glendale	\$ 2.2 million
City of Phoenix	\$ 7.1 million
Maricopa County	\$ 4.1 million

TABLE I  
CONSTRUCTION SCHEDULE FOR  
DRAINAGE FACILITIES ALONG BELL ROAD

DRAINAGE AREA	LOCATION	1987	1988	1989	1990	1991	1992	COMMENTS
1	GRAND AVENUE - AGUA FRIA							DRAINAGE AND ROADWAY PHASING, OK
2	AGUA FRIA - 115TH AVENUE 115TH AVENUE - 93RD AVENUE 93RD AVENUE - NEW RIVER							DRAINAGE AND ROADWAY PHASING, OK
3	NEW RIVER TO OUTER LOOP 83RD AVENUE - SKUNK CREEK			 				DRAINAGE AND ROADWAY PHASING, OK
4	SKUNK CREEK - 67TH AVENUE 67TH AVENUE - 51ST AVENUE 51ST AVENUE - 43RD AVENUE 43RD AVENUE - I-17			 				DRAINAGE AND ROADWAY PHASING, OK
5	I-17 - 19TH AVENUE 19TH AVENUE - CAVE CREEK							DRAINAGE AND ROADWAY PHASING, OK
6	CAVE CREEK - 7TH STREET 7TH STREET - 20TH STREET							DRAINAGE AND ROADWAY PHASING, OK
7	20TH STREET - CAVE CREEK ROAD CAVE CREEK ROAD - 36TH STREET							ROADWAY AND/OR DRAINAGE PHASING WILL HAVE TO BE MODIFIED TO ENSURE PROPER SEQUENCING
8	36TH STREET - 40TH STREET 40TH STREET - 56TH STREET 56TH STREET - SCOTTSDALE ROAD							DRAINAGE AND ROADWAY PHASING, OK

TABLE 2  
SUMMARY OF ESTIMATED COSTS

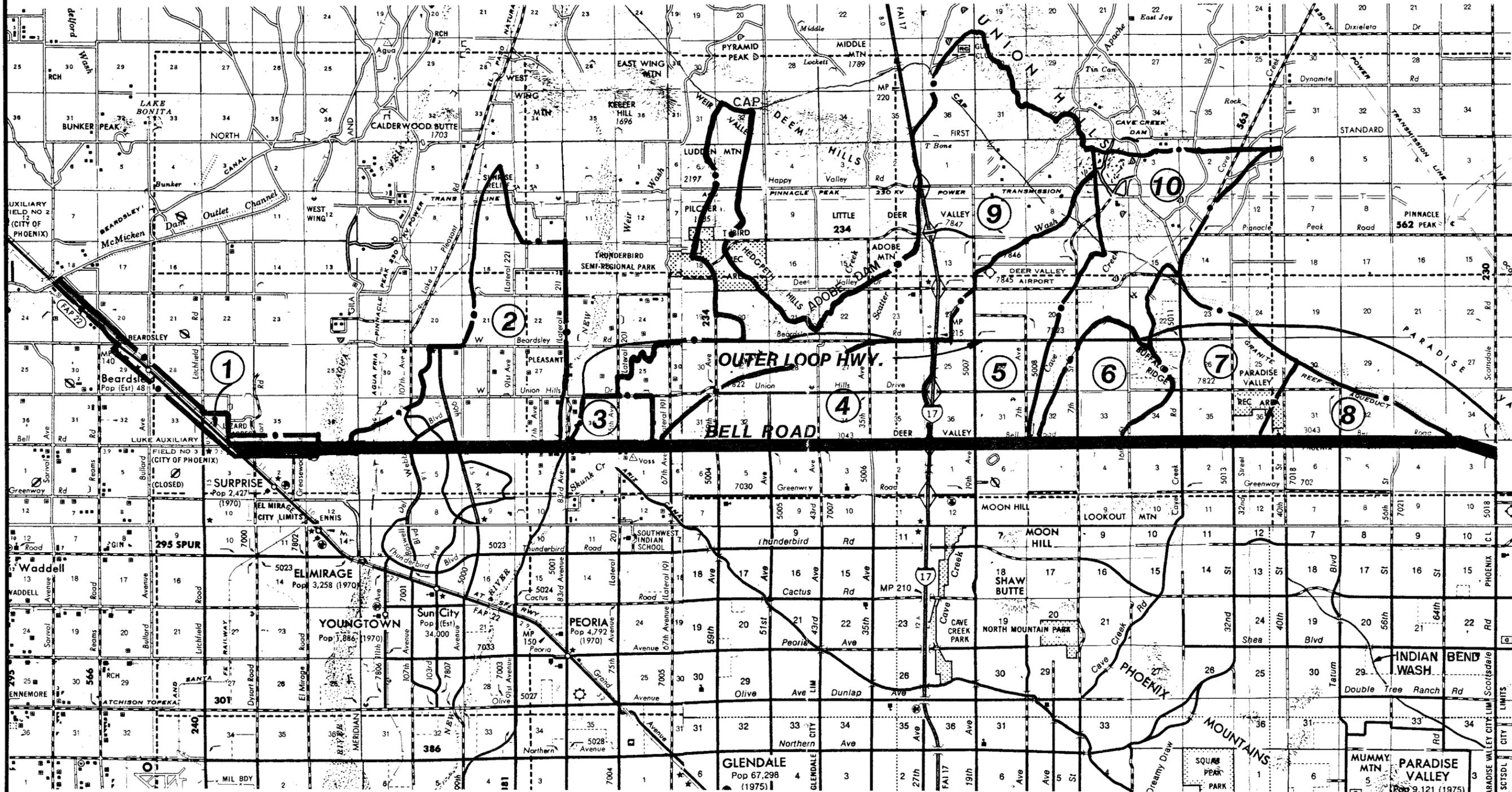
<u>LOCATION PROPOSED BY</u>	<u>TOWN OF SURPRISE</u>	<u>CITY OF PEORIA</u>	<u>CITY OF GLENDALE</u>	<u>CITY OF PHOENIX</u>	<u>MARICOPA COUNTY</u>	<u>TOTALS</u>
North of Bell Road Proposed by Glendale-Peoria ADMS	0	\$ 2,632,000	0	0	0	\$ 2,632,000
North of Bell Road Proposed by Bell Road Project Drainage Study (BRPDS)	0	\$ 2,493,000	\$ 992,000			\$ 3,485,000
North of Bell Road Proposed by Northwest Storm Drainage Study (NSDS)	0	0	0	\$ 2,507,000	0	\$ 2,507,000
North of Bell Road Proposed by North Central Area Master Storm Drainage Study (NCMSD)	0	0	0	\$ 1,972,000	0	\$ 1,972,000
North of Bell Road Proposed by Upper East Fork of Cave Creek ADMS (UEFCC)	0	0	0	\$18,981,000	\$ 6,245,000	\$ 25,226,000
North of Bell Road Proposed by Northeast Area Master Storm Drainage Study (NAMSD)	0	0	0	\$ 1,945,000	0	\$ 1,945,000
North of Bell Road Proposed by Glendale Storm Water Management Plan (SWMP)	0	0	\$ 2,141,000	0	0	\$ 2,141,000
Sub-Total	0	\$ 5,125,000	\$ 3,133,000	\$25,405,000	\$ 6,245,000	\$ 39,908,000

TABLE 2 (CONTINUED)  
SUMMARY OF ESTIMATED COSTS

<u>LOCATION PROPOSED BY</u>	<u>TOWN OF SURPRISE</u>	<u>CITY OF PEORIA</u>	<u>CITY OF GLENDALE</u>	<u>CITY OF PHOENIX</u>	<u>MARICOPA COUNTY</u>	<u>TOTALS</u>
Facilities Along Bell Road Proposed by BRPDS	\$ 110,000	\$ 641,000	\$ 2,296,000	\$ 3,799,000	\$ 1,163,000	\$ 8,009,000
Facilities Along Bell Road Proposed by UEFCC	0	0	0	\$ 3,304,000	\$ 2,921,000	\$ 6,225,000
<b>Sub-Total</b>	<b>\$ 110,000</b>	<b>\$ 641,000</b>	<b>\$ 2,296,000</b>	<b>\$ 7,103,000</b>	<b>\$ 4,084,000</b>	<b>\$ 14,234,000</b>
Facilities South of Bell Road Proposed by Glendale- Peoria ADMS	0	\$ 974,000	0	0	0	\$ 974,000
Facilities South of Bell Road Proposed by BRPDS	0	0	\$ 610,000	\$ 751,000	0	\$ 1,321,000
Facilities South of Bell Road Proposed by SWMP	0	0	\$ 5,911,000	0	0	\$ 5,911,000
Facilities South of Bell Road Proposed by NSDS	0	0	0	\$ 11,202,000	0	\$ 11,202,000
Facilities South of Bell Road Proposed by UEFCC	0	0	0	\$ 9,940,000	0	\$ 9,940,000
Facilities South of Bell Road Proposed by NAMSD	0	0	0	\$ 12,954,000	0	\$ 12,954,000
<b>Sub-Total</b>	<b>0</b>	<b>\$ 974,000</b>	<b>\$ 6,521,000</b>	<b>\$ 34,847,000</b>	<b>0</b>	<b>\$ 42,342,000</b>
<b>GRAND TOTAL*</b>	<b>\$ 110,000</b>	<b>\$ 6,740,000</b>	<b>\$ 11,950,000</b>	<b>\$ 67,355,000</b>	<b>\$ 10,329,000</b>	<b>\$ 96,484,000</b>
Channelization of East Fork of Cave Creek Wash (Cost From UEFCC ADMS Developed by Others)						\$ 10,100,000
<b>GRAND TOTAL</b>						<b>\$ 106,584,000</b>

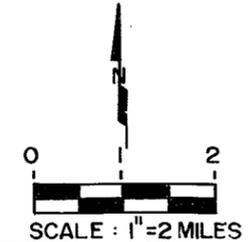
TABLE 3  
SUMMARY OF ESTIMATED COSTS  
FOR THE  
DRAINAGE FACILITIES ALONG BELL ROAD

<u>FISCAL YEAR</u>	<u>LOCATION</u>	<u>TOWN OF SURPRISE</u>	<u>CITY OF PEORIA</u>	<u>CITY OF GLENDALE</u>	<u>CITY OF PHOENIX</u>	<u>MARICOPA COUNTY</u>	<u>TOTAL</u>
1989-1990	93rd Avenue to Outer Loop	\$ 0	\$ 641,000	\$ 0	\$ 0	\$ 0	\$ 641,000
	83rd Avenue to 67th Avenue	0	0	1,105,000	0	0	1,105,000
	43rd Avenue to I-17	0	0	0	986,000	0	986,000
	19th Avenue to 7th Street	0	0	0	716,000	0	716,000
	Cave Creek Road to 40th Street	0	0	0	236,000	2,921,000	3,157,000
Sub-Total		0	\$ 641,000	\$ 1,105,000	\$ 1,938,000	\$ 2,921,000	\$ 6,605,000
1990-1991	115th Avenue to 93rd Avenue	\$ 0	\$ 0	\$ 0	\$ 0	\$ 912,000	\$ 912,000
	67th Avenue to 51st Avenue	0	0	1,191,000	0	0	1,191,000
	I-17 to 19th Avenue	0	0	0	339,000	0	339,000
	7th Street to Cave Creek Road	0	0	0	3,425,000	0	3,425,000
	40th Street to 56th Street	0	0	0	768,000	0	768,000
Sub-Total		0	0	\$ 1,191,000	\$ 4,532,000	\$ 912,000	\$ 6,635,000
1991-1992	Grand Avenue to 115th Avenue	\$110,000	\$ 0	\$ 0	\$ 0	\$ 251,000	\$ 361,000
	51st Avenue to 43rd Avenue	0	0	0	388,000	0	388,000
	56th Street to Scottsdale Road	0	0	0	245,000	0	245,000
Sub-Total		\$110,000	\$ 0	\$ 0	\$ 633,000	\$ 251,000	\$ 994,000
Total		\$110,000	\$ 641,000	\$ 2,296,000	\$ 7,103,000	\$ 4,084,000	\$ 14,234,000



**LEGEND**

-  MAJOR DRAINAGE AREA BOUNDARIES
-  MAJOR DRAINAGE AREA NUMBERS



Revisions

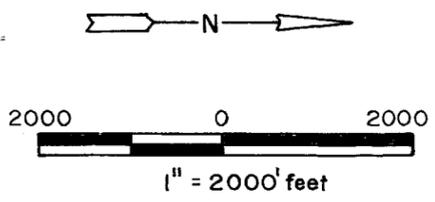
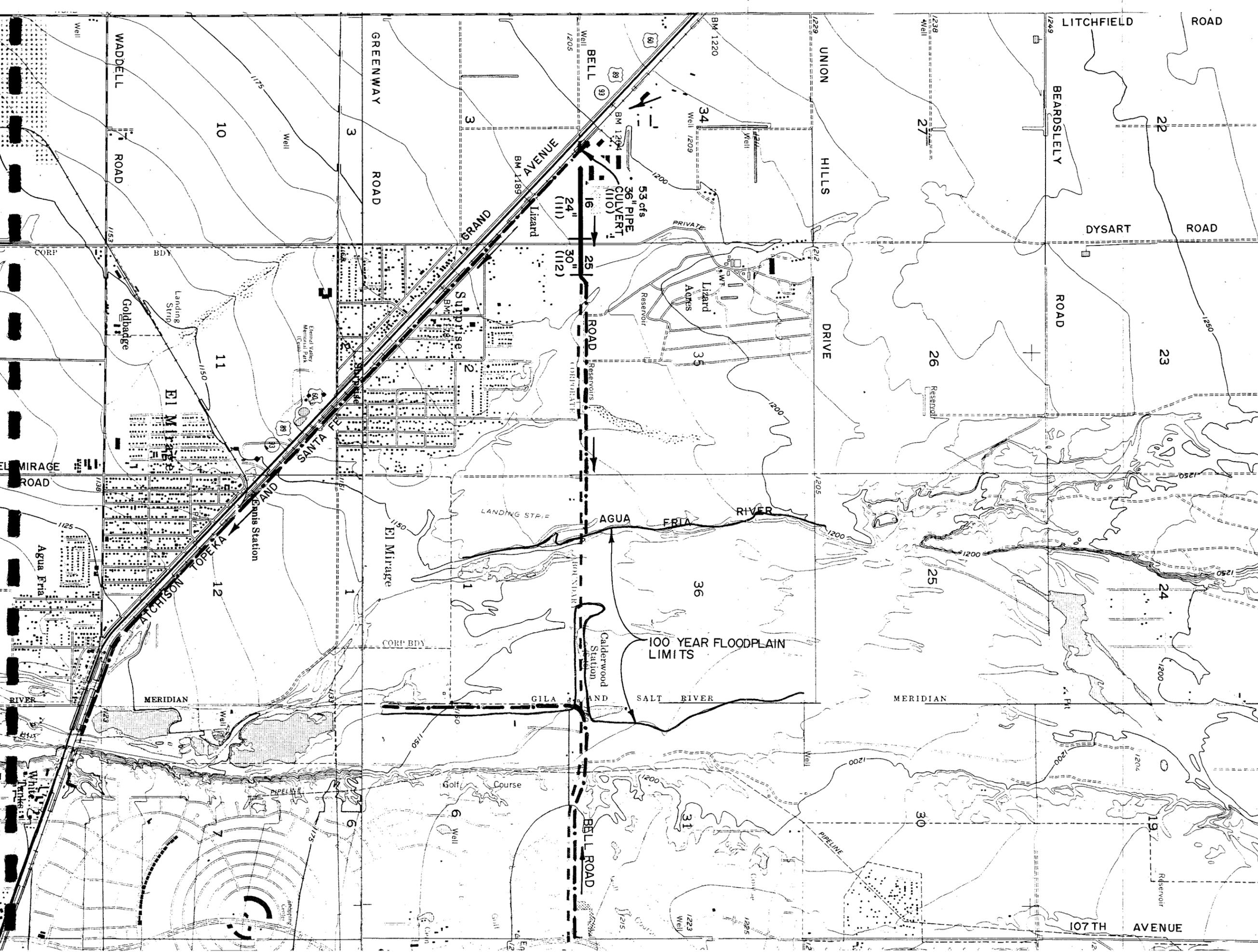
**Greiner Engineering**  
 A Greiner Engineering, Inc. Company  
 Greiner Engineering Sciences, Inc.  
 7300 N. 10th Street, Suite 100 Phoenix, Arizona 85020 602 275-5400  
 2590 North American Way Tucson, Arizona 85712 520 327-9413

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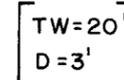
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**BELL ROAD PROJECT**  
**DRAINAGE STUDY**  
 MAJOR DRAINAGE AREAS

Date: JAN. 1987  
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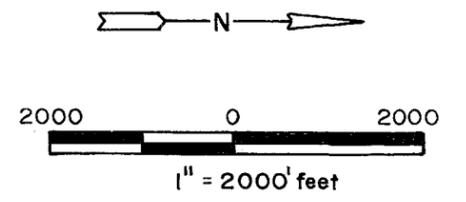
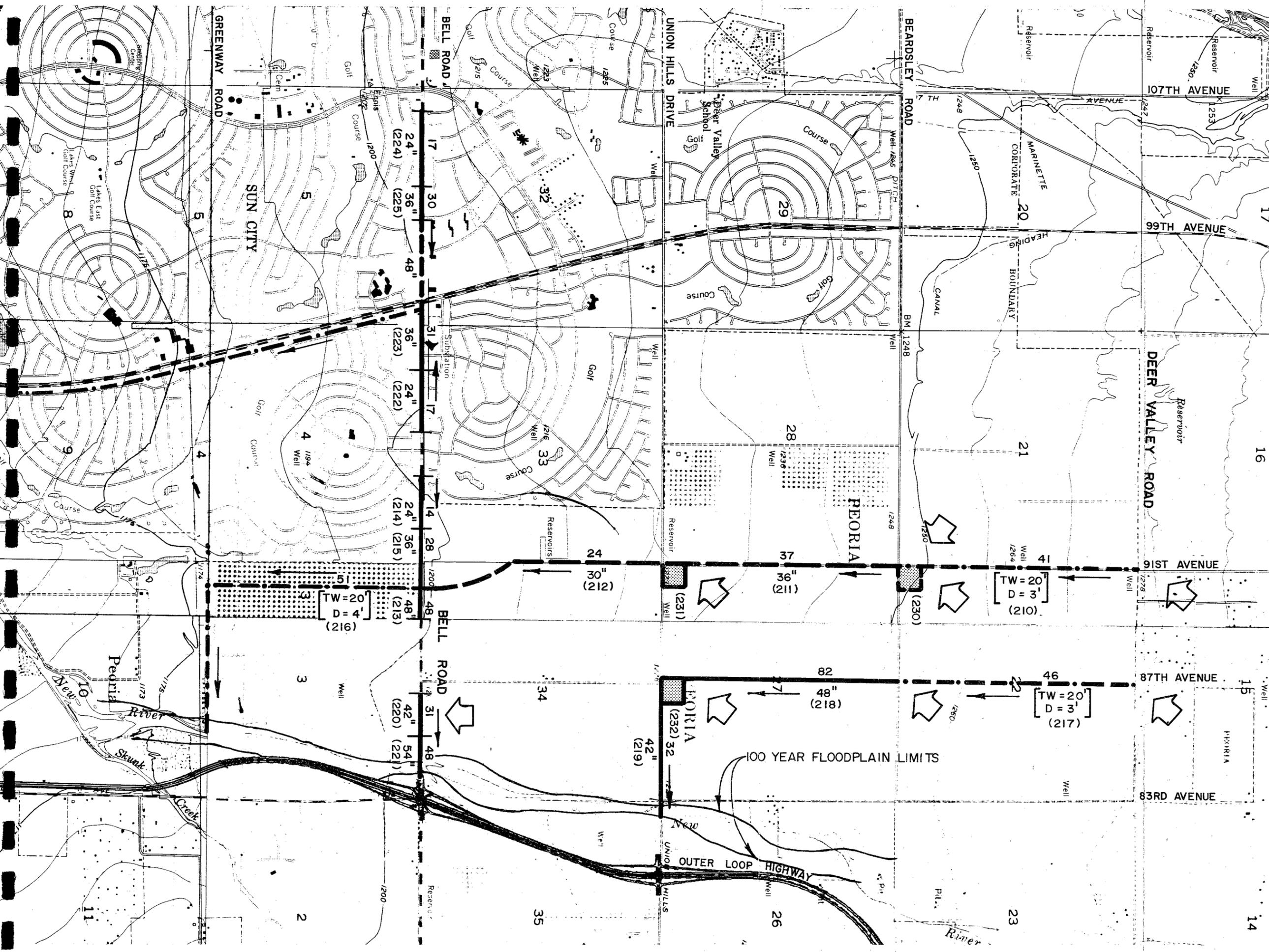
- LEGEND**
-  CONDUIT
  -  OPEN CHANNEL
  -  DETENTION BASIN
  - 51 PEAK FLOW IN CFS
  - 36" STRUCTURE SIZE FOR CONDUITS
  - (714) STRUCTURE NUMBER

- OPEN CHANNELS**
-  TOP WIDTH  
DEPTH
  -  FACILITIES PROPOSED BY THIS STUDY
  -  PROPOSED OR EXISTING FACILITIES FROM AREA MASTER DRAINAGE STUDIES

**PLATE I**  
**SELECTED PLAN**  
**DRAINAGE AREA 1&2**

BELL ROAD PROJECT  
 DRAINAGE STUDY

**Greiner**  
**Engineering**



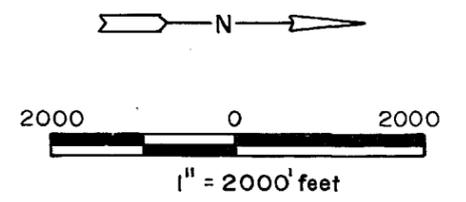
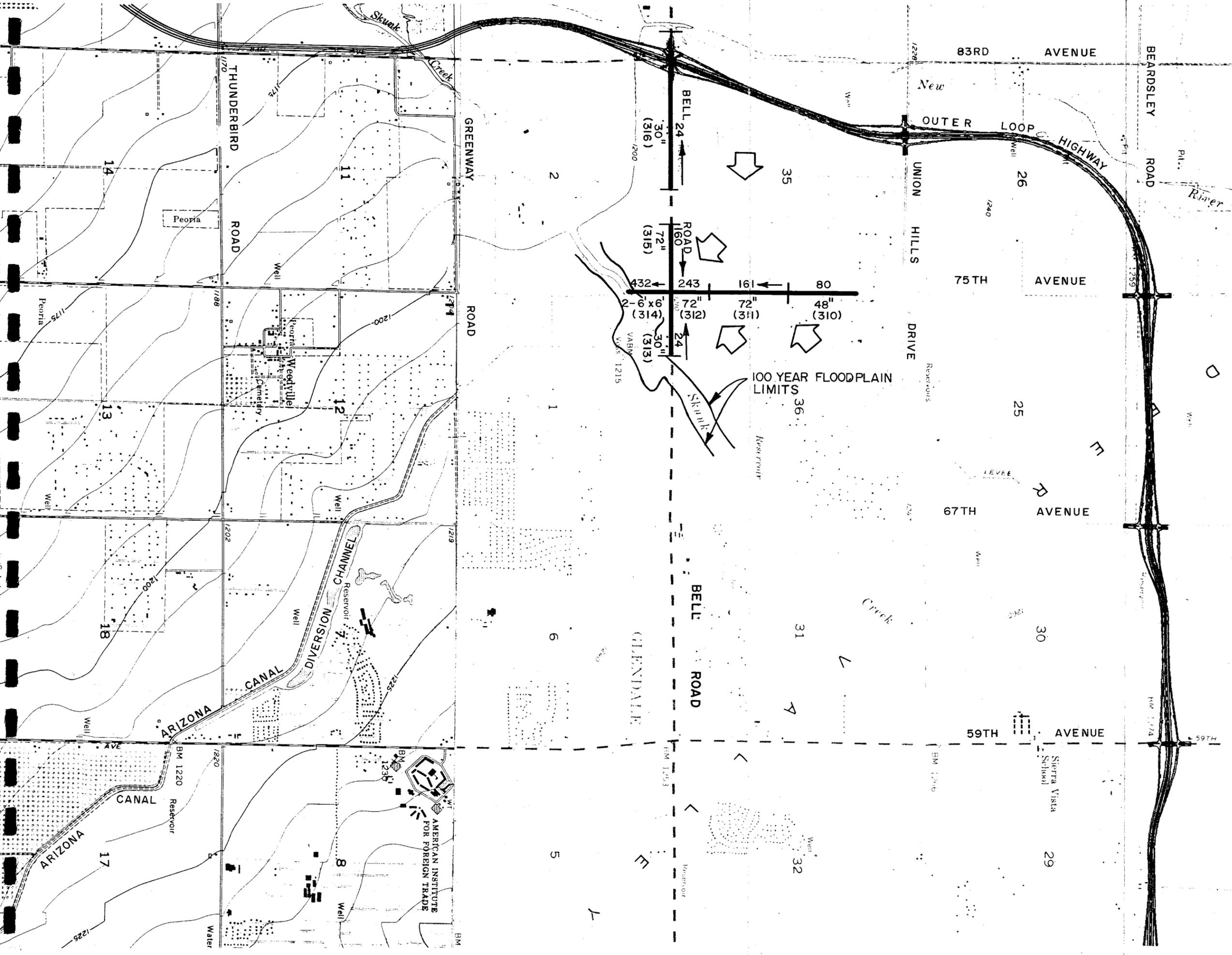
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- OPEN CHANNELS**
- TOP WIDTH  
DEPTH
  - FACILITIES PROPOSED BY THIS STUDY
  - PROPOSED OR EXISTING FACILITIES FROM AREA MASTER DRAINAGE STUDIES

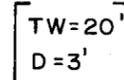
**PLATE 2**  
**SELECTED PLAN**  
**DRAINAGE AREA 2**

BELL ROAD PROJECT  
 DRAINAGE STUDY

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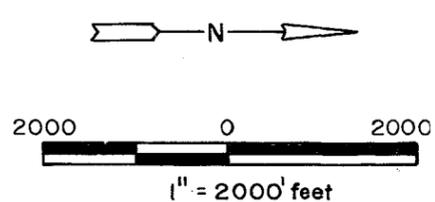
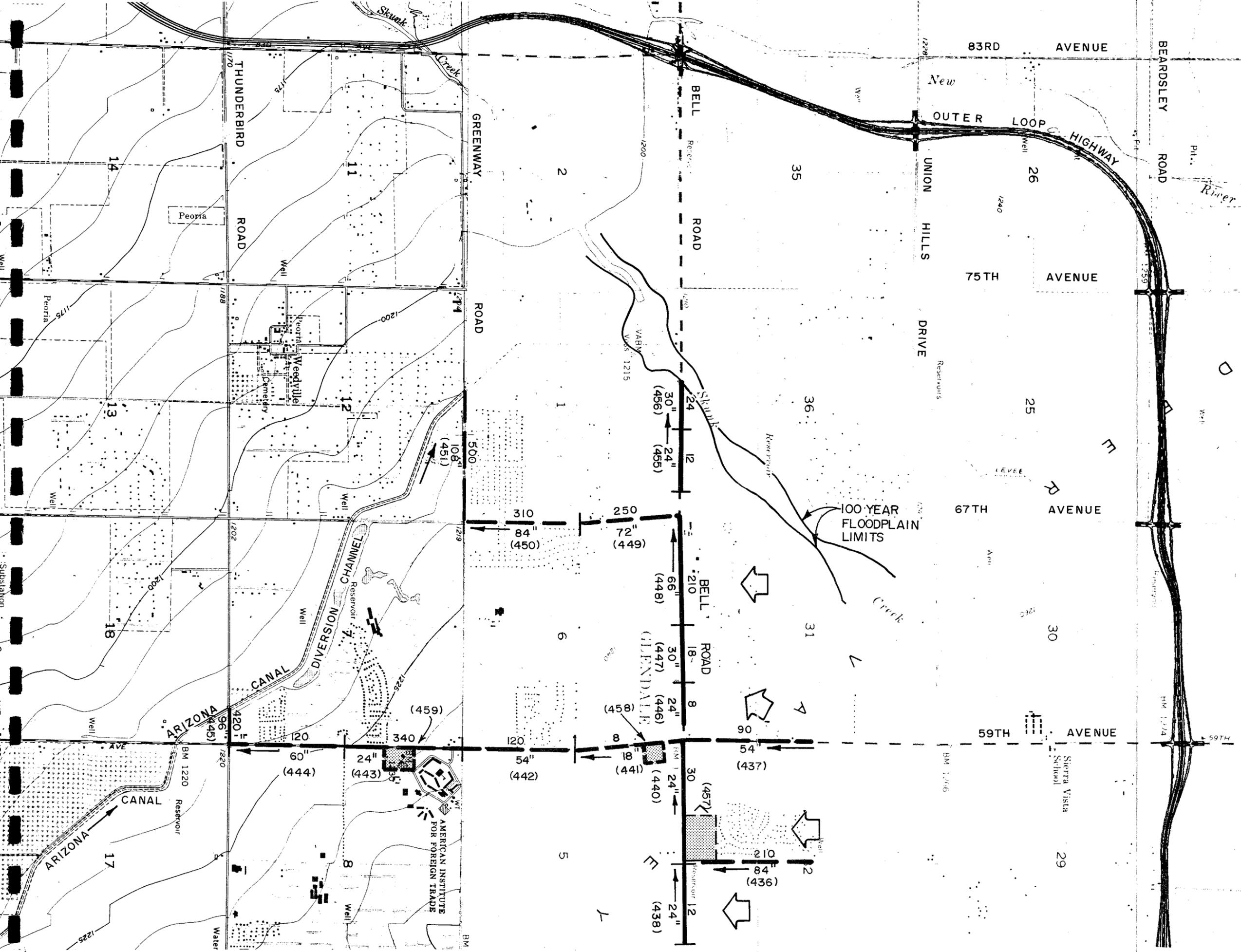
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-  TOP WIDTH  
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  -  FACILITIES PROPOSED BY THIS STUDY
  -  PROPOSED OR EXISTING FACILITIES FROM AREA MASTER DRAINAGE STUDIES

**PLATE 3**  
**SELECTED PLAN**  
**DRAINAGE AREA 3**

BELL ROAD PROJECT  
 DRAINAGE STUDY

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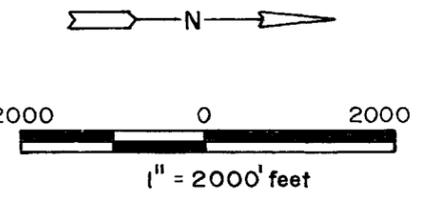
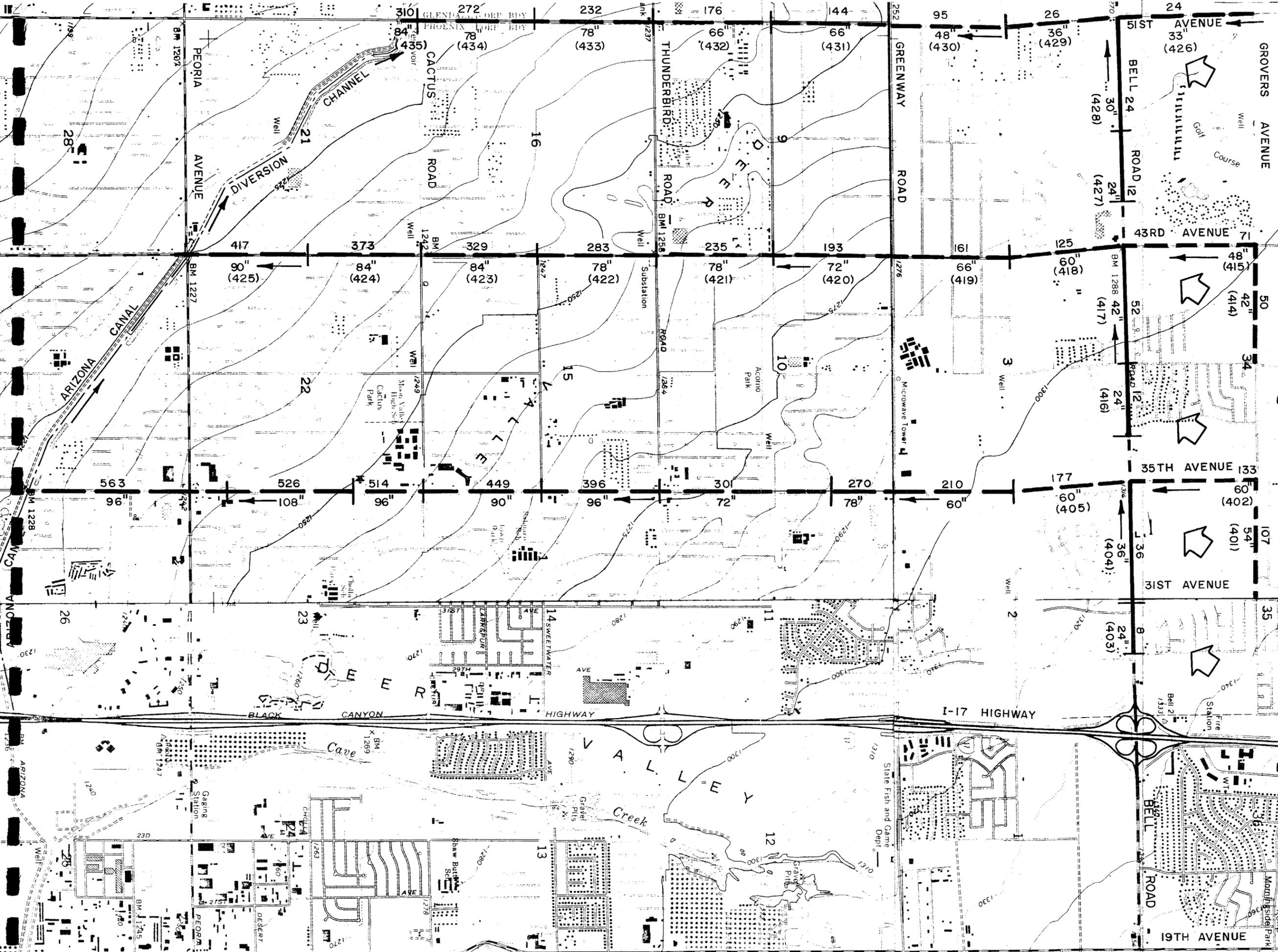


- LEGEND**
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  - OPEN CHANNEL
  - DETENTION BASIN
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- OPEN CHANNELS**
- TOP WIDTH  
DEPTH
  - FACILITIES PROPOSED BY THIS STUDY
  - PROPOSED OR EXISTING FACILITIES FROM AREA MASTER DRAINAGE STUDIES

**PLATE 4**  
**SELECTED PLAN**  
 DRAINAGE AREA 4  
 (SHEET 1 OF 2)  
 BELL ROAD PROJECT  
 DRAINAGE STUDY

**Greiner Engineering**



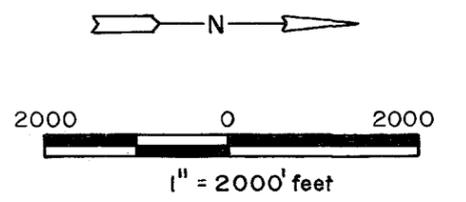
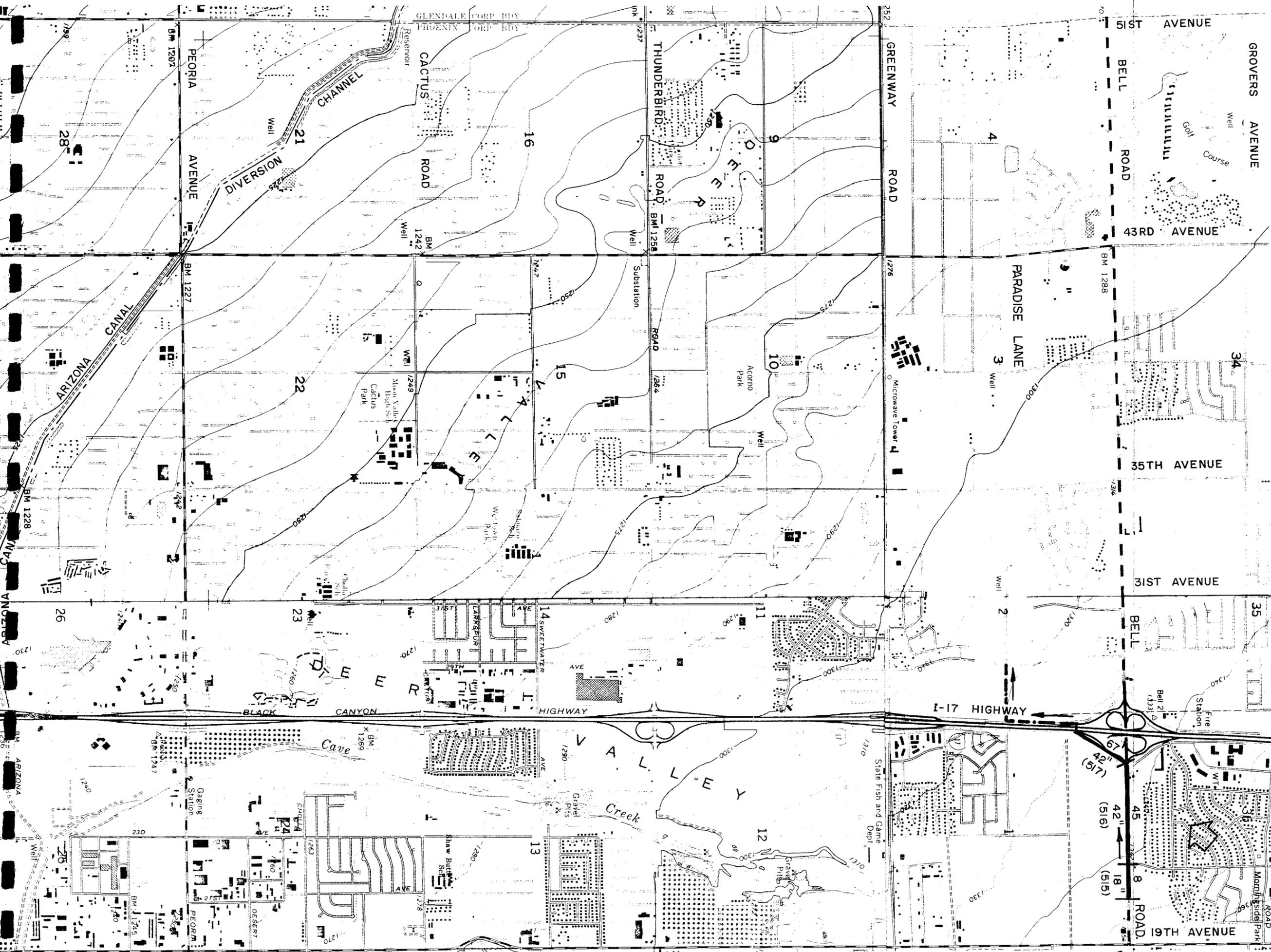
- LEGEND**
-  CONDUIT
  -  OPEN CHANNEL
  -  DETENTION BASIN
  - 51 PEAK FLOW IN CFS
  - 36" STRUCTURE SIZE FOR CONDUITS
  - (714) STRUCTURE NUMBER

- OPEN CHANNELS**
- |        |           |
|--------|-----------|
| TW=20' | TOP WIDTH |
| D=3'   | DEPTH     |
-  FACILITIES PROPOSED BY THIS STUDY
  -  PROPOSED OR EXISTING FACILITIES FROM AREA MASTER DRAINAGE STUDIES

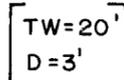
**PLATE 5**  
**SELECTED PLAN**  
 DRAINAGE AREA 4  
 (SHEET 2 OF 2)

BELL ROAD PROJECT  
 DRAINAGE STUDY

**Greiner Engineering**



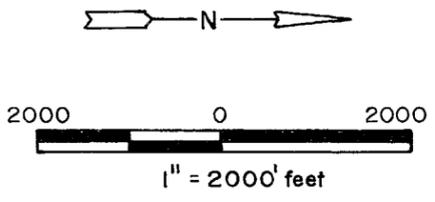
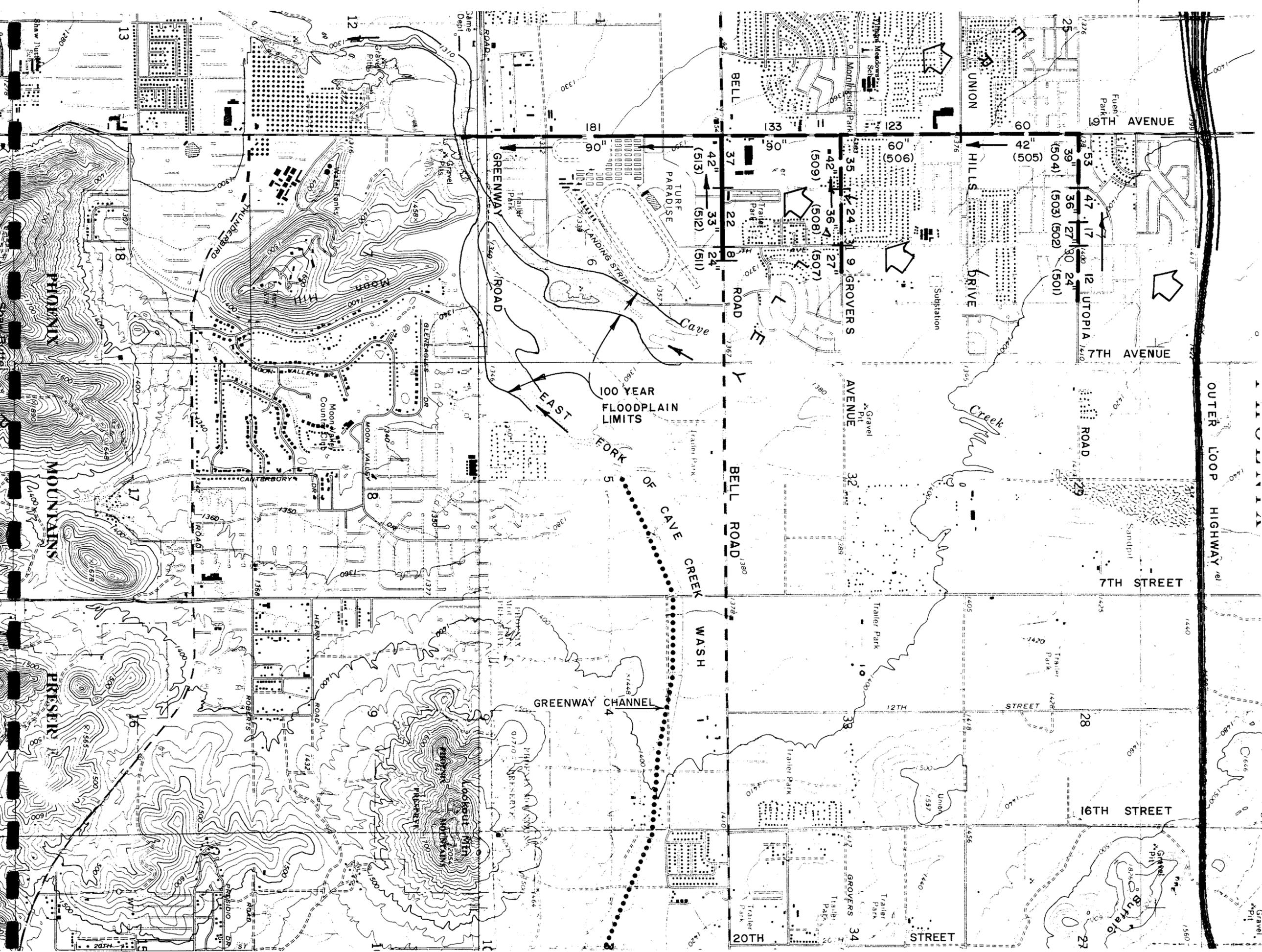
- LEGEND**
-  CONDUIT
  -  OPEN CHANNEL
  -  DETENTION BASIN
  - 51 PEAK FLOW IN CFS
  - 36" STRUCTURE SIZE FOR CONDUITS
  - (714) STRUCTURE NUMBER

- OPEN CHANNELS**
-  TOP WIDTH  
DEPTH
  -  FACILITIES PROPOSED BY THIS STUDY
  -  PROPOSED OR EXISTING FACILITIES FROM AREA MASTER DRAINAGE STUDIES

**PLATE 6**  
**SELECTED PLAN**  
 DRAINAGE AREA 5  
 (SHEET 1 OF 2)

BELL ROAD PROJECT  
 DRAINAGE STUDY

**Greiner Engineering**



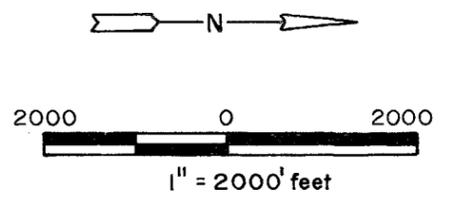
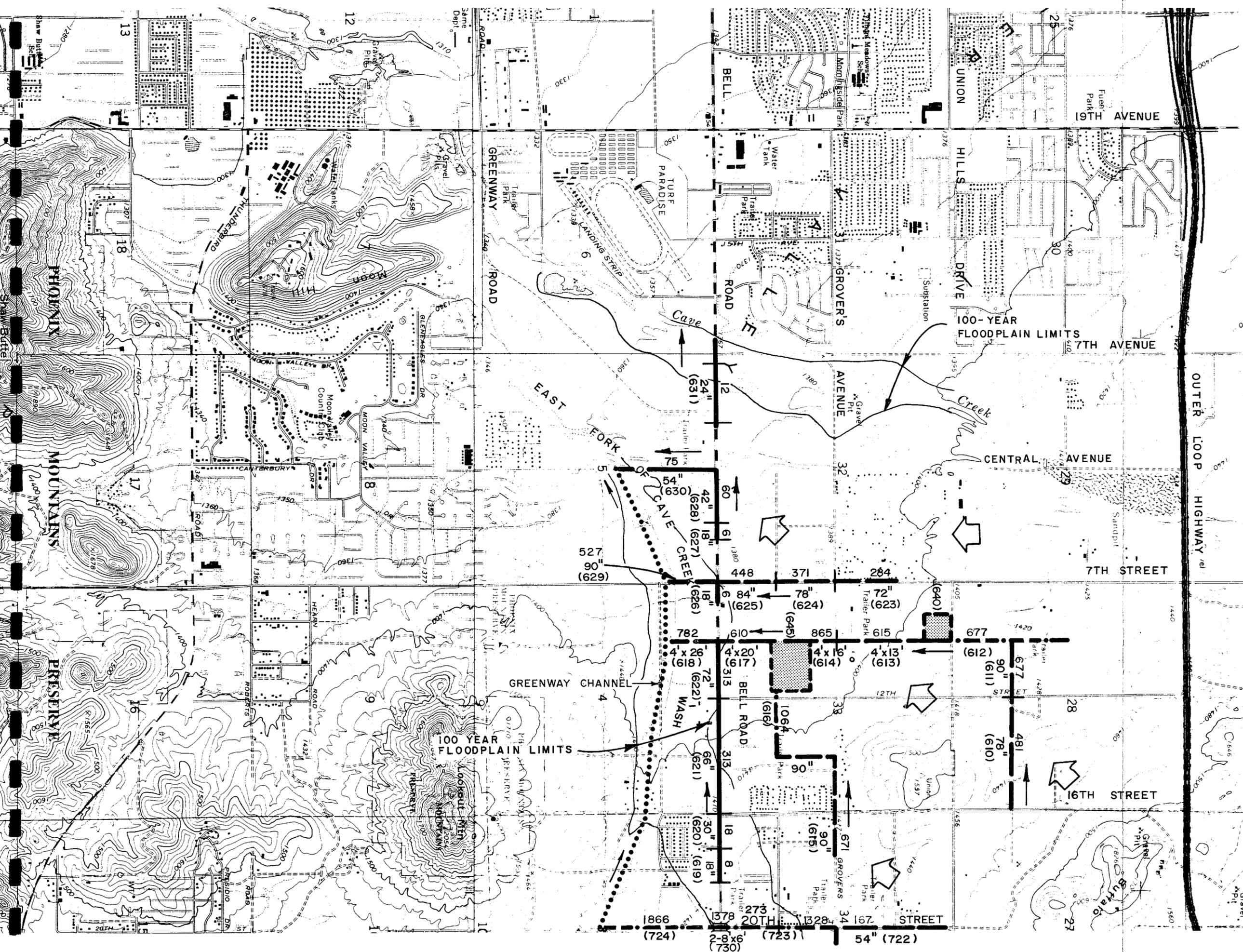
- LEGEND**
-  CONDUIT
  -  OPEN CHANNEL
  -  DETENTION BASIN
  - 51 PEAK FLOW IN CFS
  - 36" STRUCTURE SIZE FOR CONDUITS
  - (714) STRUCTURE NUMBER

- OPEN CHANNELS**
- |        |           |
|--------|-----------|
| TW=20' | TOP WIDTH |
| D=3'   | DEPTH     |
-  FACILITIES PROPOSED BY THIS STUDY
  -  PROPOSED OR EXISTING FACILITIES FROM AREA MASTER DRAINAGE STUDIES

**PLATE 7**  
**SELECTED PLAN**  
 DRAINAGE AREA 5  
 (SHEET 2 OF 2)

BELL ROAD PROJECT  
 DRAINAGE STUDY

**Greiner Engineering**



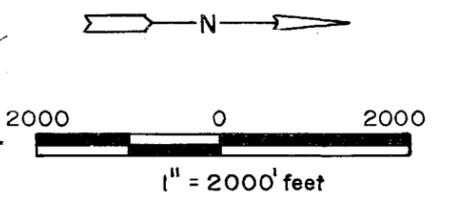
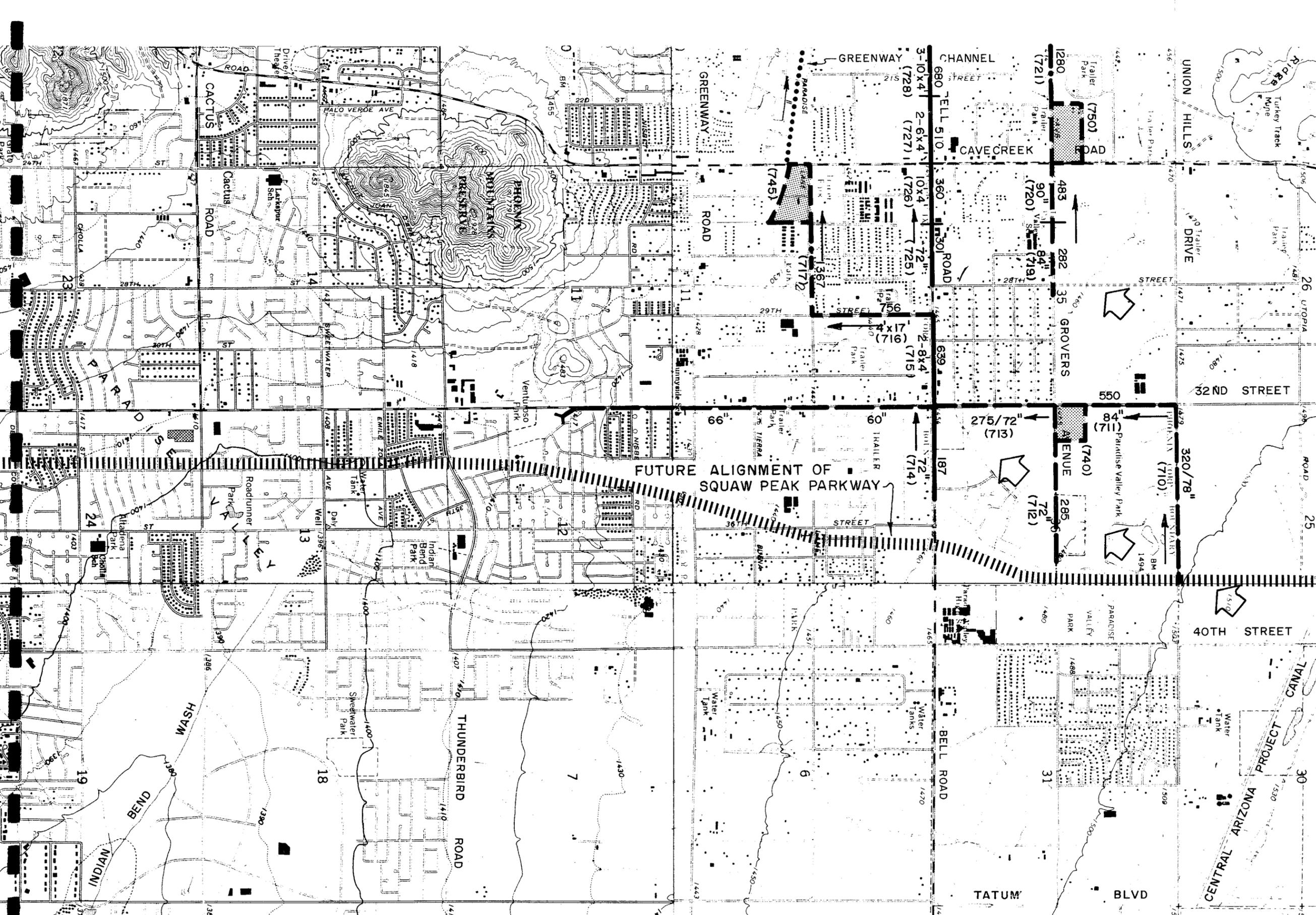
- LEGEND**
- CONDUIT
  - OPEN CHANNEL
  - DETENTION BASIN
  - 51 PEAK FLOW IN CFS
  - 36" STRUCTURE SIZE FOR CONDUITS
  - (714) STRUCTURE NUMBER

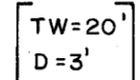
- OPEN CHANNELS**
- |        |           |
|--------|-----------|
| TW=20' | TOP WIDTH |
| D=3'   | DEPTH     |
- FACILITIES PROPOSED BY THIS STUDY
  - PROPOSED OR EXISTING FACILITIES FROM AREA MASTER DRAINAGE STUDIES

**PLATE 8**  
**SELECTED PLAN**  
**DRAINAGE AREA 687**

BELL ROAD PROJECT  
 DRAINAGE STUDY

**Greiner**  
**Engineering**

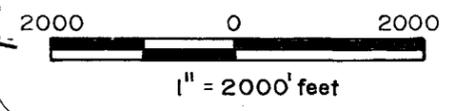
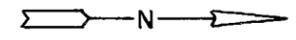
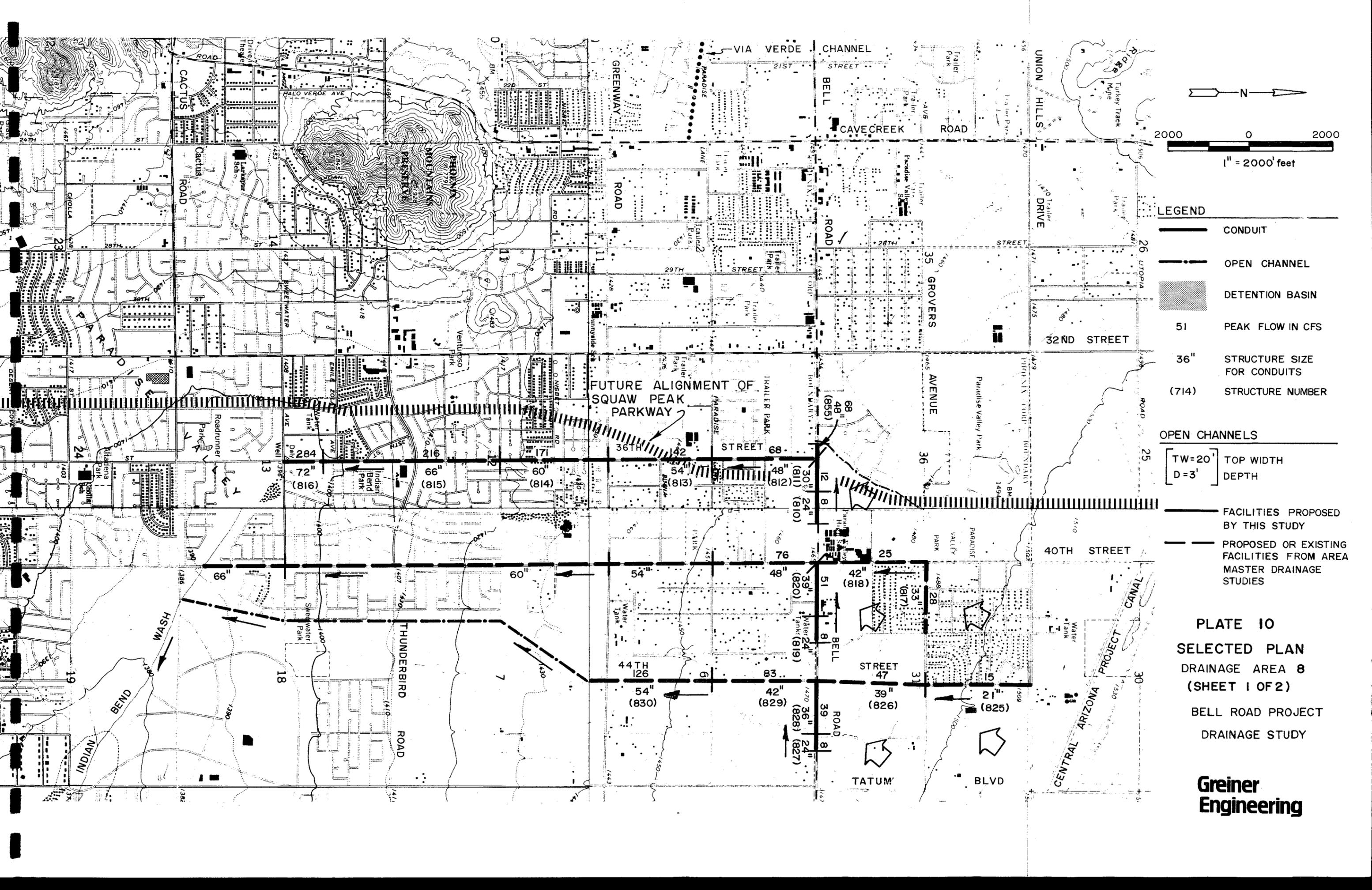


- LEGEND**
-  CONDUIT
  -  OPEN CHANNEL
  -  DETENTION BASIN
  - 51 PEAK FLOW IN CFS
  - 36" STRUCTURE SIZE FOR CONDUITS
  - (714) STRUCTURE NUMBER
- OPEN CHANNELS**
-  TOP WIDTH  
DEPTH
  -  FACILITIES PROPOSED BY THIS STUDY
  -  PROPOSED OR EXISTING FACILITIES FROM AREA MASTER DRAINAGE STUDIES

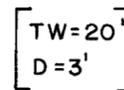
**PLATE 9**  
**SELECTED PLAN**  
**DRAINAGE AREA 7**

BELL ROAD PROJECT  
 DRAINAGE STUDY

**Greiner**  
**Engineering**

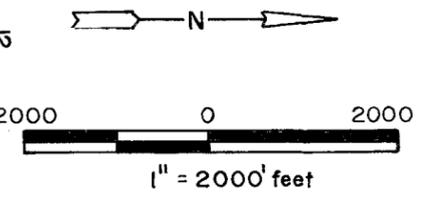


- LEGEND**
-  CONDUIT
  -  OPEN CHANNEL
  -  DETENTION BASIN
  - 51 PEAK FLOW IN CFS
  - 36" STRUCTURE SIZE FOR CONDUITS
  - (714) STRUCTURE NUMBER

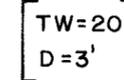
- OPEN CHANNELS**
-  TOP WIDTH  
DEPTH
  -  FACILITIES PROPOSED BY THIS STUDY
  -  PROPOSED OR EXISTING FACILITIES FROM AREA MASTER DRAINAGE STUDIES

**PLATE 10**  
**SELECTED PLAN**  
 DRAINAGE AREA 8  
 (SHEET 1 OF 2)  
 BELL ROAD PROJECT  
 DRAINAGE STUDY

**Greiner Engineering**



- LEGEND**
-  CONDUIT
  -  OPEN CHANNEL
  -  DETENTION BASIN
  - 51 PEAK FLOW IN CFS
  - 36" STRUCTURE SIZE FOR CONDUITS
  - (714) STRUCTURE NUMBER

- OPEN CHANNELS**
-  TOP WIDTH  
DEPTH
  -  FACILITIES PROPOSED BY THIS STUDY
  -  PROPOSED OR EXISTING FACILITIES FROM AREA MASTER DRAINAGE STUDIES

**PLATE II**  
**SELECTED PLAN**  
**DRAINAGE AREA 8**  
**(SHEET 2 OF 2)**  
**BELL ROAD PROJECT**  
**DRAINAGE STUDY**

**Greiner Engineering**