CITY OF PHOENIX
GREENWAY PARKWAY CHANNEL
DESIGN CONCEPT REPORT

INDEX #ST-955468

Prepared for:
Street Transportation
CITY OF PHOENIX
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Phoenix, Arizona 85034

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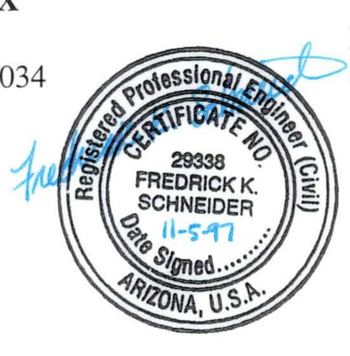

November 4, 1997
WP #96559

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1.0 INTRODUCTION

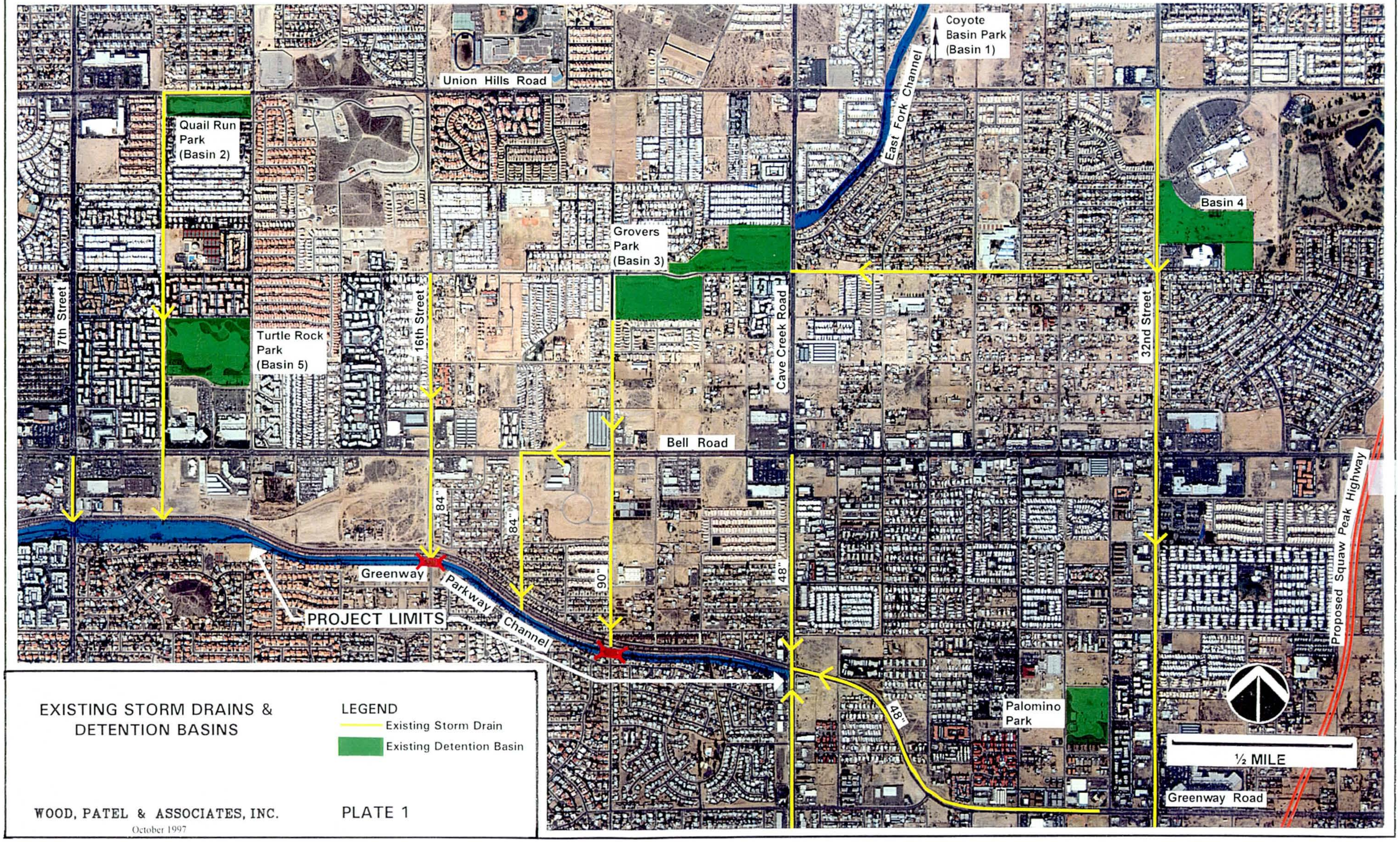
1.1 Purpose

This design concept report (DCR) is prepared for the City of Phoenix Street Transportation Department as a follow-up report to the *Greenway Parkway Channel Design Review Report* by Wood, Patel & Associates, Inc. (Wood/Patel) and the *Greenway Channel Analysis, Alternatives Analysis Report* by Dibble & Associates Consulting Engineers (Dibble). The purpose of this report is to develop and evaluate various channel options to improve the hydraulic characteristics of the channel to contain the 100-year flood peak between Cave Creek Road and approximately 12th Street. Once an alternative has been selected after the review and agency concurrence, the City of Phoenix will pursue preparation of design and construction plans. The plans will be used in conjunction with the application for a Conditional Letter of Map Revision (CLOMR) for the East Fork of Cave Creek Wash.

1.2 Background

The Greenway Parkway Channel was built in 1989 as part of a regional flood control improvement project in the northeast area around the East Fork of Cave Creek Wash. Plate 1 shows an aerial photo of the study area. In the process of preparing a Letter of Map Revision (LOMR) for the Federal Emergency Management Agency (FEMA), Dibble discovered certain inadequacies within the channel system. The City of Phoenix directed Dibble to review and find alternatives to mitigate the inadequacies. Dibble, in turn, prepared a report entitled *Alternatives Analysis Report - Greenway Channel* in March 1995. The Dibble report has identified the discrepancies within the existing channel and conceptually evaluated available alternatives to mitigate the discrepancies. The preliminary cost estimate prepared in March 1995 for the proposed channel design modifications resulted in approximately $4.5 to $6 million dollars excluding engineering, construction and administration costs. Detailed hydraulic analyses, including backwater calculations by Dibble were not available during the preparation of this DCR. Therefore, we have assumed that the Dibble recommended alternative meets the District's design guidelines, e.g., flow regimes, freeboard, etc.

GREENWAY PARKWAY CHANNEL



EXISTING STORM DRAINS &
DETENTION BASINS

LEGEND
Existing Storm Drain
Existing Detention Basin

WOOD, PATEL & ASSOCIATES, INC.
October 1997

PLATE 1

Due to this major cost issue, the City of Phoenix Street Transportation Department requested Wood/Patel for a second option on the design review. Wood/Patel submitted the results of their design review in a report entitled *City of Phoenix, Greenway Parkway Channel Design Review Report* in March 1997. Subsequent to the design review phase, the City authorized the second phase of scope of work. The second phase required an option evaluation to conceptually identify any new cost-effective flood mitigation measures. As part of the second phase analysis, Wood/Patel is submitting the results of the evaluation and recommended channel improvement plan in this report.

1.3 Existing Conditions

The existing channel consists of rock-filled gabion basket side slopes placed in a stepped fashion, and a 4-inch-thick concrete-lined bottom with welded wire fabric for reinforcement. The channel system also includes a 36-inch diameter low-flow storm drain along the entire channel length reinforced concrete box culverts (RCBC) at 16th and 20th Streets, and several major storm drain lateral connects. Plate 1 shows an aerial photo of the study area and approximate location and sizes of major storm drain laterals connecting to the channel.

Based on the previous review by Wood/Patel titled *City of Phoenix, Greenway Parkway Channel Design Review Report*, the channel fails to meet many of the Flood Control District of Maricopa County (District) channel design criteria. These inadequacies have been documented in Wood/Patel's previous report.

Previous reports and analysis indicate that the existing channel and storm drains are inadequate to handle the required flow rates in the existing condition. The proposed condition will lower the hydraulic grade line (HGL) and energy grade line (EGL), thereby increasing the capacity of the existing storm drain system and reducing the amount of sheet flow entering the channel.

1.4 Conclusions/Recommendations

Based on the design review of the Greenway Parkway Channel as documented in Wood/Patel's previous report, the following conclusions were drawn:

- The hydrology, as well as the basin modeling, appears to be adequate.

- The channel appears to have been built as proposed by the design plans based on the two field verified (surveyed) cross sections.

- The channel is inadequate to handle the 100-year flood peaks per the HEC-RAS analysis.

- The channel design does not meet some basic hydraulic parameters and appears to be structurally inadequate.

- The channel design hinders the performance of the 12th, 16th, and 20th Street storm drains.

Based on extensive alternative development analysis and cost comparisons, Wood/Patel has identified an alternative which would mitigate the drainage inadequacies and improve the structural capabilities. The selected alternative would maintain most of the existing channel gabions and both RCBC crossings while minimizing impacts to the existing channel. The following paragraphs briefly describe the recommended alternative. For a detailed description, please see section 3.9 titled *Deepen Existing Channel, But Maintain Existing RCBC's.*

The entire channel bottom would be replaced with a thicker lining. The lining thickness would range from six to seven inches depending on the proposed channel velocities. In addition, approximately 4,930 feet of the existing 36-inch RCP would be removed and 1,180 feet would be replaced. The section of channel from 20th Street to 18th Street and 16th Street to 13th Street would have a low flow "V" in the bottom instead of the 36-inch RCP. Approximately 1,900 feet of channel would be widened on the north side to remove critical channel constrictions. Channel widening would be from 12th Street, east approximately 1,400 feet and from 20th Street, east approximately 500 feet. The existing RCBC's would be maintained in their existing conditions. The section downstream of the RCBC's will be deepened to increase the hydraulic conveyance by lowering the outfall elevation thereby decreasing the tailwater at the box outlet.

2.0 ANALYSIS APPROACH REVIEW

2.1 Hydrology

Wood/Patel performed a comparison and review of the TR-20 hydrologic analysis used in the design of the Greenway Channel and a separate TR-20 model used for the CLOMR package prepared by Dibble. This analysis in documented in Wood/Patel's Design Review Report. The following is a brief overview of Wood/Patel's findings:

- Runoff Curve Numbers in some drainage sub-basins were updated in the CLOMR model to reflect current (as of 1993) and future land use data.

- The CLOMR drainage sub-basins were subdivided based on more detailed field investigations.

- The CLOMR TR-20 model incorporates the now-existing detention basins #1, #2, #3, #4, and #5 proposed in the *Cave Creek ADMS* as well as numerous storm drains within the watershed.

- The CLOMR TR-20 model produces lower peak discharges in the Greenway Parkway Channel near Cave Creek Road, but higher discharges at 20th Street and downstream, compared to the *Cave Creek ADMS* model.

- The review showed that both TR-20 models appear to be reasonable and used the methodology accepted by the District at the time of the *Cave Creek ADMS* report.

2.2 Channel Hydraulics

Wood/Patel performed a review and analysis of the hydraulics for the Greenway Parkway Channel in the existing condition and documented these channel deficiencies. This analysis is documented in Wood/Patel's previous report; however, the following is a brief overview of Wood/Patel's findings:

- Wood/Patel collected ground survey cross section data at two pre-selected locations to verify the channel geometry and as-built elevations.

- Required freeboard (FB) is computed according to the following formula: $FB=0.25(Y+V^2/2g)$. Where "Y" is the depth of flow in feet, "V" is the average channel velocity in fps, and "g" is the acceleration of gravity in ft/sec^2. The minimum freeboard value for rigid channels shall be one foot for subcritical and two feet for supercritical flows.

- Wood/Patel's HEC-RAS model shows that the water surface elevation for both the design flows and newer CLOMR flows is above the channel banks at many locations.

- The results of the HEC-RAS model also show that the flow regime is near critical (Froude number between 0.86 and 1.13) in many areas, and that it varies from subcritical to supercritical along the study reach.

- Many transitions in the channel bottom width exist, which in supercritical flow reaches, can lead to undesirable standing waves. The channel bottom profile is also quite irregular, contributing to undulations in the water surface profile.

- The 4-inch bottom slab thickness of the channel is inadequate for the existing flow conditions. According to District and ADOT channel design guidelines, a minimum slab thickness of 6-inches is required for channels wide enough to accommodate maintenance vehicles. Based on existing channel velocities, a thicker channel bottom may also be required.

- A hydraulic report was not available for the original channel design; therefore, a review of the original design was not possible.

- In the existing condition, the capacity of the off-site storm drains entering the channel from the north are severely reduced while peak

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- Many transitions in the channel bottom width exist, which in supercritical flow reaches, can lead to undesirable standing waves. The channel bottom profile is also quite irregular, contributing to undulations in the water surface profile.

- The 4-inch bottom slab thickness of the channel is inadequate for the existing flow conditions. According to District and ADOT channel design guidelines, a minimum slab thickness of 6-inches is required for channels wide enough to accommodate maintenance vehicles. Based on existing channel velocities, a thicker channel bottom may also be required.

- A hydraulic report was not available for the original channel design; therefore, a review of the original design was not possible.

- In the existing condition, the capacity of the off-site storm drains entering the channel from the north are severely reduced while peak flows are occurring in the Greenway Parkway Channel due to the high HGL and EGL elevations.

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Explanation req'd.

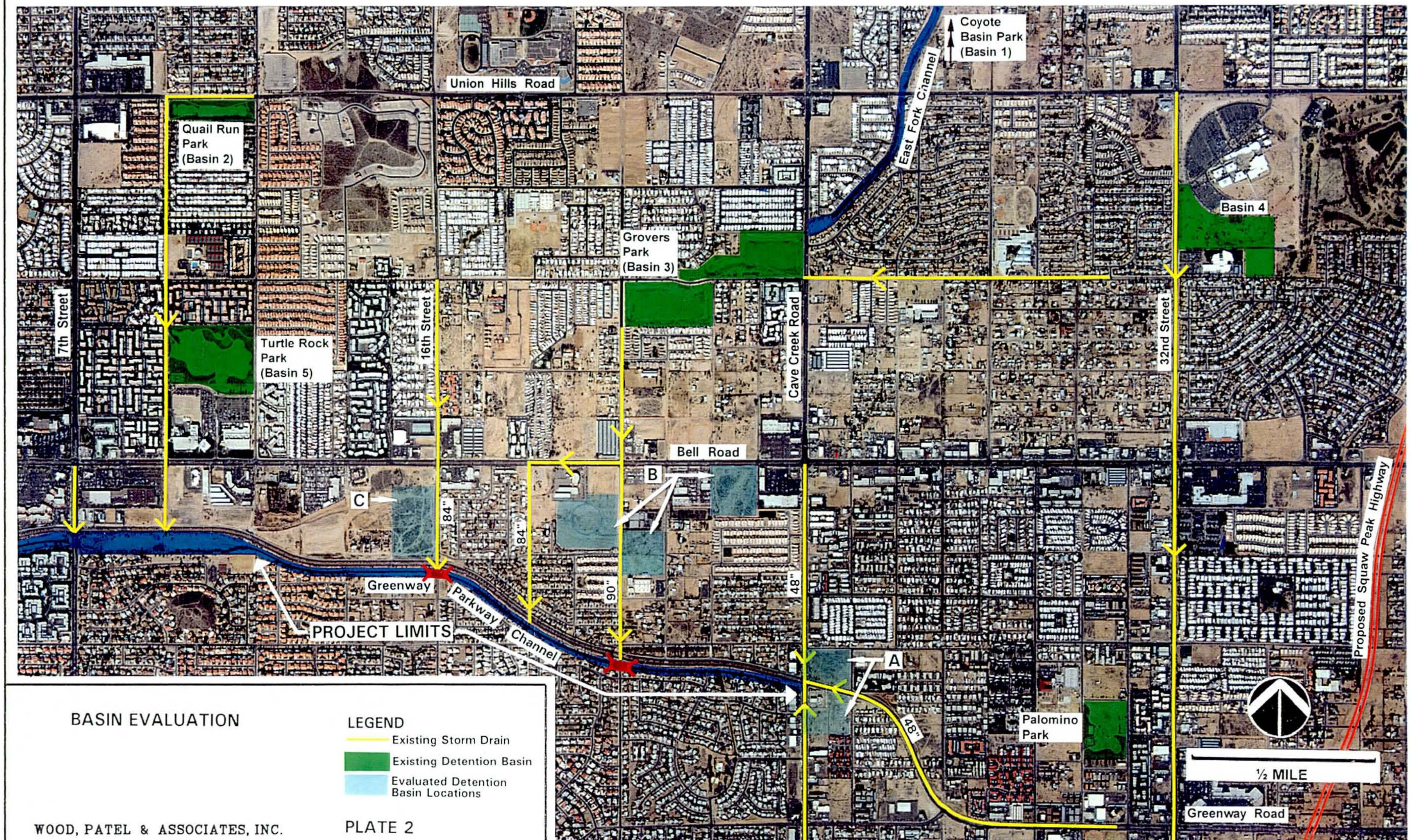
flows are occurring in the Greenway Parkway Channel due to the high HGL and EGL elevations.

3.0 PROPOSED DRAINAGE IMPROVEMENTS

The following section discusses drainage improvements proposed at various locations along the Greenway Parkway Channel as part of Wood/Patel's project. Conceptually, on a qualitative basis, numerous alternative options were evaluated throughout the analysis process. Both upgrading the existing channel and off-site improvements to reduce the channel inflow were investigated as part of the alternative analysis process. Based on the hydrologic model, the channel conveys flows from contributing areas from both the north and south directions. With the large existing off-site detention basins capturing large amounts of off-site flows, locating additional sites for new detention basins to reduce peak flows in the channel is difficult.

Plate 2 shows the detention basin locations evaluated during the alternative selection process.

GREENWAY PARKWAY CHANNEL



BASIN EVALUATION

LEGEND

Existing Storm Drain

Existing Detention Basin

Evaluated Detention Basin Locations

WOOD, PATEL & ASSOCIATES, INC.

October 1997

PLATE 2

3.1 Detention Basin at Cave Creek Road/Greenway Parkway

A new detention basin (depicted as Basin A on Plate 2) on the vacant parcels at the northeast and northwest corners of Cave Creek Road and Greenway Parkway were evaluated as an option to decrease flows entering the channel. The proposed detention basin would retain all storm flows entering the Greenway Parkway Channel at Cave Creek Road. The detention basin would intercept the storm drains located in Cave Creek Road and Greenway Parkway as well as overland flows east of Cave Creek Road. From Wood/Patel's preliminary analysis, the detention basin would lower the flow rate in the Greenway Parkway Channel by approximately 2000 cfs. Based on the revised hydraulic analysis, various sections of the channel were still unable to contain these reduced flows. Overtopping of the culverts and exceeding channel capacity down stream of 16th Street occurred. The estimated cost for the detention basin without channel improvements was $ 4.8 million.

Based on the preliminary analysis, the proposed detention basin was rejected since it will not solve the channel conveyance problem as well as the excessive land acquisition and construction costs.

3.1 Detention Basin at Cave Creek Road/Greenway Parkway

A new detention basin (depicted as Basin A on Plate 2) on the vacant parcels at the northeast and northwest corners of Cave Creek Road and Greenway Parkway were evaluated as an option to decrease flows entering the channel. The proposed detention basin would retain all storm flows entering the Greenway Parkway Channel at Cave Creek Road. The detention basin would intercept the storm drains located in Cave Creek Road and Greenway Parkway as well as overland flows east of Cave Creek Road. From Wood/Patel's preliminary analysis, the detention basin would lower the flow rate in the Greenway Parkway Channel by approximately 2000 cfs. Based on the revised hydraulic analysis, various sections of the channel were still unable to contain these reduced flows. Overtopping of the culverts and exceeding channel capacity down stream of 16th Street occurred. The estimated cost for the detention basin without channel improvements was $ 4.8 million.

Based on the preliminary analysis, the proposed detention basin was rejected since it will not solve the channel conveyance problem as well as the excessive land acquisition and construction costs.

3.2 Deepening Existing Detention Basins

Wood/Patel evaluated the possibility of increasing the sizes of three existing upstream detention basins to allow for the storage of all storm flows entering the basins. The four basins are basins 1, 2, 3 and 5 as shown on Plate 2. Enlarging the detention basin would require excavating the basins deeper, installing pump station facilities, and re-landscaping since the existing basins are currently used as recreational facilities. Also, if the basins are deepened, there would be stormwater ponding in the detention basins each time there is excessive rainfall creating a potential maintenance problem and hindering the basin's use as a recreational facility. Also, an annual maintenance costs would be increased because of the pump station facilities. The estimated cost for increasing the available storage within the existing detention basins is $5.1 million for all four basin enlargements.

Based on the preliminary analysis, the enlargement of the existing detention basins was rejected due to high construction costs. A complete evaluation to determine whether this option alleviates the channel conveyance problem was not completed since the estimated construction costs were excessive and because of the adverse impacts on recreational use. However, based on the existing outflow rates from the detention basins, enlarging the basins may not alleviate the channel conveyance problem. Channel improvements or an additional detention basin may be required. For these reasons, this option was not evaluated further.

3.3 Detention Basin 20th Street/Bell Road

With this option, a new detention basin would be placed near 20th Street and Greenway Parkway as well as west of Cave Creek Road on the north and south sides of Bell Road (depicted as Basin "B" on Plate 2). Several potential basin locations were evaluated throughout the analysis. Most of the vacant land available is located north of Greenway Parkway near or fronting Bell Road. Property in this area would be expensive to acquire due to the properties commercial use potential.

The proposed detention basin would intercept flows entering the channel from 16^{th} Street north of Bell Road. However, after estimating the contributing drainage area to the proposed basin, the remaining flow rates in the channel would still be larger than the conveyance capacity. For this reason, this option was not evaluated further.

3.4 Detention Basin 16^{th} Street/Greenway Parkway

With this option, a new detention basin would be constructed on the vacant parcel at the northwest corner of 16^{th} Street and Greenway Parkway (depicted as Basin C, Plate 2). The detention basin would intercept flows entering the channel from 16^{th} Street north of Greenway Parkway. However, after estimating the contributing drainage area to the basin, the remaining flow rates in the channel were still larger than the conveyance capacity. For this reason, this option was not evaluated further.

3.5 Decreasing the Manning's "n" value (Shotcrete over gabions)

With this option, the existing gabion baskets would be covered with shotcrete to reduce the manning's "n" value (roughness coefficient) to approximately 0.022 from 0.035 and thereby increasing the conveyance capacity of the channel. However, with the reduced roughness coefficient, the conveyance capacity of the channel is still not sufficient. For this reason, this option was not evaluated further.

3.6 Maintain Existing Channel with Clear Span Roadway Crossings

With this option, the channel would be maintained in it's existing condition and the RCBC's at 20th and 16th Streets would be removed. A clear span bridge would be constructed in their place. This option would eliminate the backwater condition caused by the RCBC's. After a hydraulic model was created to simulate this condition, Wood/Patel verified that not only are the RCBC's undersized with the existing vertical profile but, the channel is undersized at various locations. Even with the RCBC's removed, flow exceeds channel capacity as various locations regardless of the culvert sizes used. Therefore, this option was not evaluated further.

3.7 Maintain Existing Vertical Profile but Widen Channel

As an option, Wood/Patel evaluated an alternative similar to Dibble's option which included keeping the existing vertical channel profile and widening the channel on the north side only. In doing so, the vertical profile would be maintained and the irregularities in the channel bottom contributing to undulations in the water surface profile would remain. A hydraulic model was developed to simulate this option which showed that replacing the existing RCBC's would be required. The City of Phoenix has requested that the existing pedestrian bridge at 20th Street not be relocated and remain in its current condition. Therefore, widening of the channel would be performed on the south side only. Due to right-of-way restrictions, this is not possible without acquiring additional land. Land acquisition costs for this project were not included in the Cost Estimate. Also, the existing meandering sidewalk and screening vegetation would be reduced or eliminated. Based on impacts to the surrounding neighborhood and similarity of this option to Dibble's selected alternative, this alternative was not evaluated further. For a comparison purpose, however, Dibble's cost analysis was updated to reflect 1997 costs. See Table 3 in Exhibit 1 for the updated cost analysis. The updated estimated probable construction costs for this option is similar to Dibble's alternative estimate of $5.5 million (1997 dollars).

3.8 Maintain Existing Channel Width, but Smoother Vertical Profile

With this option, the existing channel cross-section would be maintained while the channel profile is modified to maintain a consistent slope between reaches. The existing gabion baskets would be connected to the new concrete bottom lining where the new profile is lower than the existing profile elevation. A hydraulic model was developed to simulate this option which showed that replacing the existing RCBC's would be required. However, removing the irregularities in the bottom profile does not eliminate the channel conveyance inefficiencies. For this reason, this option was not evaluated further.

3.9 Deepen Existing Channel, but Maintain Existing RCBC's

This option is the recommended option based on Wood/Patel's alternative selection analysis and cost comparisons. This option will maintain most of the existing channel gabions and both RCBC crossings while minimizing visual and aesthetic impacts to the existing channel and surrounding landscaping.

The entire channel bottom would be replaced with a thicker concrete lining ranging from six to seven inches based on the proposed channel velocities. The new channel lining could use larger aggregate and be pressure washed to expose the aggregate faces simulating the existing gabion look. Aesthetically, this would blend the existing gabions with the new concrete lining limiting the visual impact to the public. During the design phase, the increased roughness can be used to keep the proposed velocities based on existing gabion requirements within a desirable range. Therefore, existing RCBC's would be maintained in their existing conditions with the exceptions of the wing walls where the larger diameter storm drains connect. (See photos in Exhibit 4.) The section downstream of the culvert RCBC's will be modified to increase the hydraulic conveyance by lowering the channel outfall, thereby decreasing the tailwater at the box outlet.

3.9.1 Channel Design Information

A review of the hydraulic analysis developed for the recommended alternative indicates that for isolated locations within the channel reached, flow regimes would exist where the froude number would be between 0.86 and 1.13. Ultimately, long reaches with a froude number in this range should be avoided during the design phase. However, since the channel is already existing constrained by the right-of-way limitations in a very urbanized area, with an objective of maintaining as much of the existing channel as possible without risking channel failure, this cannot be completely avoided. Also, in most cases where this condition exists, it may be possible to decrease the channel velocity by adjusting the channel slope and/or Manning's roughness coefficient to minimize areas where this condition exists. In channel reaches where these froude numbers exist, the numbers are close to the 0.9 or 1.1 limits, meaning that the flow regime is generally near the stable condition. To ensure proper operating condition during more frequent storm events, the 10-year storm was analyzed. This analysis indicted existing channel gabions and both RCBC crossings while minimizing visual and aesthetic impacts to the existing channel and surrounding landscaping.

The entire channel bottom would be replaced with a thicker concrete lining ranging from six to seven inches based on the proposed channel velocities. The new channel lining could use larger aggregate and be pressure washed to expose the aggregate faces simulating the existing gabion look. Aesthetically, this would blend the existing gabions with the new concrete lining limiting the visual impact to the public. During the design phase, the increased roughness can be used to keep the proposed velocities based on existing gabion requirements within a desirable range. Therefore, existing RCBC's would be maintained in their existing conditions with the exceptions of the wing walls where the larger diameter storm drains connect. (See photos in Exhibit 4.) The section downstream of the culvert RCBC's will be modified to increase the hydraulic conveyance by lowering the channel outfall, thereby decreasing the tailwater at the box outlet.

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Preliminary investigation indicates that in a few locations, particularly where the freeboard is near the minimum, conditions may exist where additional protection may be required above the existing gabions because the existing ground is located above the top of gabions. The existing ground line was estimated based on the District's Arizona Canal Diverison Channel ADMS topographic maps with two foot contours. Field investigation revealed that in some locations, the top of gabions may be over one foot lower than adjacent existing ground. During the design phase and once more accurate topo has been developed from field survey, these conditions can be identified and resolved properly.

Based on the District and ADOT guidelines, the maximum slope of required maintenance ramps is 10 percent. To maintain longitudinal access in the channel bottom, ramps are required at all drop structure locations.

Other channel design issues that may require resolution during the design phase include:

- weepholes in the channel side banks to reduce hydrostatic pressure,

- geotechnical borings to verify channel stability with the proposed 1.5:1 side slopes,

- survey and channel as-built information, and

- pothole of existing utility crossings to identify potential relocations.

Wood/Patel's Design Review Report based on the research data provided by the gabion manufacturer concluded that the existing gabions were acceptable at velocities of up to 16 fps. However, the hydraulic analysis developed for the recommended alternative indicates that in isolated locations, channel velocities may reach 19 fps. HEC-RAS estimates channel velocity as the average velocity in the cross-section. Velocity at the bottom and near the sides will be lower, while the center velocity will be larger. Based on information contained in the Urban Storm Drainage Criteria Manual (Reference 4), velocity along the channel sides can be estimated as 0.7 times the average velocity. Using this information, the estimated channel velocity near the gabions would be 0.7*19 fps = 13.3 fps (see Exhibit 3). This value is lower than the maximum recommended. Therefore, the gabions should be adequate in this condition. Based on the HEC-RAS model, results of velocities near the side bank edges, which are based on flow distribution, indicated velocities near the gabions would be less than 3 fps. Wood/Patel feels that the 13 fps estimated by the previous method is more reasonable and therefore should be utilized for this report. It should be noted that in isolated areas where the allowable velocity becomes a critical issue, structure enhancement to the gabions can be made by grouting.

The description of channel improvements are divided into three separate reaches. The first reach is from 12th Street east to 16th Street, the second reach is from 16th to 20th Street and, the third reach is from 20th Stree to Cave Creek Road. Preliminary Plan and Profile Drawings have bee developed, including typical sections and details, and are included in th Appendix as Exhibit G. The estimated probable construction cost i 1997 dollars is $4.1 million. See Exhibit 1 and Table 1 for an outlin of probable quantities, unit costs, and probable construction costs.

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3.9.2 Reach One

For the first reach, the recommended option requires the existing gabions on the north side of the channel to be removed and replaced to allow widening of the channel an additional seven to nine feet. The limits of the widening extend from 12th Street to the east approximately 1400 feet. The widening of the channel from 12th Street east eliminates the existing constriction and would match the existing 39 foot bottom width from 12th to 16th Streets. The channel profile would match the existing inlet invert elevation at 12th Street while the channel invert elevation near the outlet of the 16th Street RCBC would be approximately 5.14 feet lower. By creating a lower channel bottom elevation immediately downstream of the existing 16th Street RCBC, the hydraulic conveyance of the RCBC is modified increasing its conveyance capacity. This allows the RCBC to convey the design flow rate without overtopping the roadway. However, the HGL freeboard would be approximately 1.0 foot and a berm or flood wall may be required around the top of the RCBC and gabions to ensure no overtopping of flows will occur. An alternative solution to increase the freeboard would be to lower the proposed channel invert immediately downstream. To reduce the proposed channel velocity, a Manning's roughness coefficient value of 0.025 (grouted rip-rap or large aggregate embedded in the concrete lining) was used for this reach. Per discussions with City staff, a longitudinal ramp would be installed at the outlet of the RCBC's to allow channel bottom access for maintenance vehicles from 12th Street to Cave Creek Road.

Based on preliminary evaluations, it appears that at 12th Street, where the new channel width transitions to the existing downstream channel, a new energy dissipation structure will be required. The section downstream of 12th Street is a natural dirt channel with desert vegetation side slopes and low velocities whereas, the new upstream channel section will be in a supercritical flow regime with velocities in the 18 fps range. With the deepening of the channel, approximately 2,100 feet of existing 36-inch CIPP will be removed. The low flow

3.9.2 Reach One

For the first reach, the recommended option requires the existing gabions on the north side of the channel to be removed and replaced to allow widening of the channel an additional seven to nine feet. The limits of the widening extend from 12th Street to the east approximately 1400 feet. The widening of the channel from 12th Street east eliminates the existing constriction and would match the existing 39 foot bottom width from 12th to 16th Streets. The channel profile would match the existing inlet invert elevation at 12th Street while the channel invert elevation near the outlet of the 16th Street RCBC would be approximately 5.14 feet lower. By creating a lower channel bottom elevation immediately downstream of the existing 16th Street RCBC, the hydraulic conveyance of the RCBC is modified increasing its conveyance capacity. This allows the RCBC to convey the design flow rate without overtopping the roadway. However, the HGL freeboard would be approximately 1.0 foot and a berm or flood wall may be required around the top of the RCBC and gabions to ensure no overtopping of flows will occur. An alternative solution to increase the freeboard would be to lower the proposed channel invert immediately downstream. To reduce the proposed channel velocity, a Manning's roughness coefficient value of 0.025 (grouted rip-rap or large aggregate embedded in the concrete lining) was used for this reach. Per discussions with City staff, a longitudinal ramp would be installed at the outlet of the RCBC's to allow channel bottom access for maintenance vehicles from 12th Street to Cave Creek Road.

14th street alignment

Based on preliminary evaluations, it appears that at 12th Street, where the new channel width transitions to the existing downstream channel, a new energy dissipation structure will be required. The section downstream of 12th Street is a natural dirt channel with desert vegetation side slopes and low velocities whereas, the new upstream channel section will be in a supercritical flow regime with velocities in the 18 fps range. With the deepening of the channel, approximately 2,100 feet of existing 36-inch CIPP will be removed. The low flow

!!!

CIPP could be replaced, or a low flow "V" can be constructed in the channel bottom. The cost estimate prepared assumes a low flow "V" would be installed to minimize construction costs. However, Table 2 in Exhibit 1 includes replacing the 36-inch CIPP from 20th to 13th Street. The additional cost is estimated at $635,000 including contingencies, engineering, and construction administration.

3.9.3 Reach Two

For the second reach, the recommended option requires no additional widening of the channel. However, the channel depth and vertical profile will be modified. The channel invert elevation at the upstream end of the 16th Street RCBC would be maintained while the channel invert elevation at the outlet of the 20th Street RCBC would be approximately 6.12 feet lower. By creating a lower channel bottom elevation immediately downstream of the existing 20th Street RCBC, the hydraulic conveyance of the RCBC are modified from the existing conditions. This allows the RCBC to convey the design flow rate without overtopping the roadway. However, the available HGL freeboard would only be approximately 0.8 feet and a berm or floodwall may be required around the top of the RCBC and gabions to ensure no overtopping of flows will occur. An alternative solution to increase the freeboard would be to lower the proposed channel invert immediately downstream. A Manning's "n" roughness coefficient of 0.015 (float finish) was used for the concrete lining in this reach. With the deepening of the channel, approximately 2,830 feet of existing 36-inch RCP will be removed and 1,180 feet replaced. The replacement is required since the storm drain at 18th Street will be lower than the new channel bottom. The 36-inch RCP will convey low flows under the channel to a point downstream of 16th Street where the 36-inch storm drain would discharge back into the channel and conveyed west in another 36-inch RCP or a low flow "V".

Channel slope is reduced.

CIPP?

Which one

should it be the existing 84" storm drain

CIPP?

the pipe stops before the 16th street.

CIPP could be replaced, or a low flow "V" can be constructed in the channel bottom. The cost estimate prepared assumes a low flow "V" would be installed to minimize construction costs. However, Table 2 in Exhibit 1 includes replacing the 36-inch CIPP from 20th to 13th Street. The additional cost is estimated at $635,000 including contingencies, engineering, and construction administration.

3.9.3 Reach Two

For the second reach, the recommended option requires no additional widening of the channel. However, the channel depth and vertical profile will be modified. The channel invert elevation at the upstream end of the 16th Street RCBC would be maintained while the channel invert elevation at the outlet of the 20th Street RCBC would be approximately 6.12 feet lower. By creating a lower channel bottom elevation immediately downstream of the existing 20th Street RCBC, the hydraulic conveyance of the RCBC are modified from the existing conditions. This allows the RCBC to convey the design flow rate without overtopping the roadway. However, the available HGL freeboard would only be approximately 0.8 feet and a berm or floodwall may be required around the top of the RCBC and gabions to ensure no overtopping of flows will occur. An alternative solution to increase the freeboard would be to lower the proposed channel invert immediately downstream. A Manning's "n" roughness coefficient of 0.015 (float finish) was used for the concrete lining in this reach. With the deepening of the channel, approximately 2,830 feet of existing 36-inch RCP will be removed and 1,180 feet replaced. The replacement is required since the storm drain at 18th Street will be lower than the new channel bottom. The 36-inch RCP will convey low flows under the channel to a point downstream of 16th Street where the 36-inch storm drain would discharge back into the channel and conveyed west in another 36-inch RCP or a low flow "V".

CIPP ?

Which one

should it be the existing 84" storm drain

CIPP ?

the pipe stops before the 16th street.

CIPP could be replaced, or a low flow "V" can be constructed in the channel bottom. The cost estimate prepared assumes a low flow "V" would be installed to minimize construction costs. However, Table 2 in Exhibit 1 includes replacing the 36-inch CIPP from 20th to 13th Street. The additional cost is estimated at $635,000 including contingencies, engineering, and construction administration.

3.9.3 Reach Two

For the second reach, the recommended option requires no additional widening of the channel. However, the channel depth and vertical profile will be modified. The channel invert elevation at the upstream end of the 16th Street RCBC would be maintained while the channel invert elevation at the outlet of the 20th Street RCBC would be approximately 6.12 feet lower. By creating a lower channel bottom elevation immediately downstream of the existing 20th Street RCBC, the hydraulic conveyance of the RCBC are modified from the existing conditions. This allows the RCBC to convey the design flow rate without overtopping the roadway. However, the available HGL freeboard would only be approximately 0.8 feet and a berm or floodwall may be required around the top of the RCBC and gabions to ensure no overtopping of flows will occur. An alternative solution to increase the freeboard would be to lower the proposed channel invert immediately downstream. A Manning's "n" roughness coefficient of 0.015 (float finish) was used for the concrete lining in this reach. With the deepening of the channel, approximately 2,830 feet of existing 36-inch RCP will be removed and 1,180 feet replaced. The replacement is required since the storm drain at 18th Street will be lower than the new channel bottom. The 36-inch RCP will convey low flows under the channel to a point downstream of 16th Street where the 36-inch storm drain would discharge back into the channel and conveyed west in another 36-inch RCP or a low flow "V".

3.9.4 Reach Three

For the third reach, the recommended option requires the existing gabions on the north side of the channel to be removed for about 500 L.F. and replaced to allow widening of the channel. More specifically, the limits of the removal/replacement extends from 20th Street to the east approximately 500 feet. The widening of the channel from 20th Street east eliminates the existing constriction and would maintain the 37 feet width upstream of 20th Street. The existing vertical profile and 36-inch low flow storm drain will be maintained in the existing condition, but the channel bottom lining must be replaced to meet the District's standard requirements based on the proposed HEC-RAS modeled channel velocities.

What is the flow regime sub/super?

3.9.5 Explanation of Cost Estimates

Per the City of Phoenix staff request, Dibble & Associate's cost estimate was revised to reflect 1997 construction unit costs as well as modification of the estimate to include 7-inch thick concrete channel lining and other items which were included in Wood/Patel's estimate. This allows an "apples to apples" cost comparison of the recommended alternatives. See Tables 1, 2, and 3 in Exhibit 1 for probable construction cost estimates. See Exhibit 7 for Minutes of the Meeting with City Staff on October 6, 1997.

4.0 CONCLUSIONS

Options are available to increase the conveyance capacity of the Greenway Parkway Channel to contain the CLOMR flow rate developed by Dibble & Associates. Wood/Patel's alternative evaluation did not discover an economical off-site detention basin alternative which would eliminate the need to upgrade the existing channel. However, based on a more detailed evaluation, Wood/Patel did develop an alternative which reduces the overall improvement construction cost when compared to results from the previous Alternative Analysis Report, with a potential savings of approximately $1.4 million dollars. Also, the recommended alternative reduces the channel construction visual impact, construction time schedule and maintains the existing culvert crossings minimizing impacts to the surrounding neighborhoods. It will have a slight disadvantage, however. For a portion of channel reach, the nuisance flow will be routed on the surface of the channel bottom. This will result in an adverse visual impact together with some added maintenance concerns.

The benefit realized by the recommended alternative, however, far outweighs the minor nuisance flow concerns.

5.0 RECOMMENDATIONS

Based on Wood/Patel's alternative selection analysis, option 3.9 *"Deeper Existing Channel, but Maintain Existing RCBC'S"*, is recommended based on estimated probable construction costs, impacts to surrounding neighborhoods and visual aesthetics. It is also recommended that the City and appropriate agency review and concur with the recommended alternative. Once concurred by the City and agency, it is Wood/Patel's recommendation to develop design plans and apply for a CLOMR from FEMA prior to construction of the channel improvements.

Based on the preliminary hydraulic analysis downstream of the project limits at 12th Street, it is recommended that the channel reach from 12th Street to a few hundred feet downstream of 7th Street be re-analyzed. This is to ensure that the recommended upstream improvements from this report do not adversely impact the natural channel section and to ensure that the 7th Street RCBC is also adequate to convey the CLOMR flows.

specially when flow U/S of 12th st. is supercritical

This issue was discussed with the City of Phoenix on October 6, 1997, and the City concurred with this recommendation. However, it was agreed upon to defer this analysis to a later date.

6.0 REFERENCES

1 Arizona Department of Transportation, *Channel Lining Design Guidelines,* February, 1989.

2. Chow, Ven Te, PhD, *Open Channel Hydraulics*, McGraw-Hill Book Company, New York-Toronto-London, 1959.

3. Colorado State University, *Hydraulic Test to Develop Design Criteria for the Use of Reno Mattresses,* March 1984.

4. Dibble & Associates Consulting Engineers, *Alternative Analysis Report*, March 1995.

5. Flood Control District of Maricopa County, *Drainage Design Manual for Maricopa County, Arizona, Volume II, Hydraulics,* January 28, 1996.

6. Flood Control District of Maricopa County, *ACDC ADMS*, 2-Foot Contour Interval, date not listed.

7. Hook Engineering, Inc. for City of Phoenix, *Greenway Parkway, from 7th Street to Cave Creek Road, Project P-861013*, March, 1989.

8. NBS-Lowry, Inc., *Upper East Fork Cave Creek ADMS*, October, 1987.

9. NBS-Lowry, Inc., *Upper East Fort Cave Creek Detention Area Sizing Study*, June, 1989.

10. NBS-Lowry, Inc., Volume II, Hydraulic, *Upper East Fort Cave Creek Channel CLOMR Submittal*, March, 1993.

11. NBS-Lowry, Inc., *Upper East Fork Cave Creek Channel, CLOMR*, March, 1993.

12. Urban Drainage and Flood Control District, Denver, *Urban Storm Drainage Criteria Manual*, 1968.

13. U.S. Army Corps of Engineers, Hydraulic Engineering Center, *HEC-RAS River Analysis User's Manual*, Version 2.0, April 1997.

14. U.S. Department of Transportation, *FHA HEC #15, Riprap Design*, 1967.

15. Wood, Patel & Associates, Inc., *"City of Phoenix Greenway Parkway Channel Design Review Report*, March, 1997.

APPENDIX

EXHIBITS

Exhibit 1

Cost Estimates

TABLE 1
Probable Construction Costs

November 4, 1997

GREENWAY PARKWAY CHANNEL
City of Phoenix

Index# ST-896829
W/P # 96559.00

CHANNEL ALTERNATIVE ANALYSIS
COST ANALYSIS, OPTION 3.9

DESCRIPTION: (DEEPEN CHANNEL) TRAPEZOIDAL SECTION BELOW GABION BASKETS, MINIMAL 36" RCP

MAJOR ELEMENTS:

ITEM	DESCRIPTION	UNIT PRICE	UNIT	QUANTITY	AMOUNT
1	Mobilization (6.5% of Costruction)	$199,600.00	LS	1	$199,600
2	Traffic Control	$15,000.00	LS	1	$15,000
3	Remove 36" CIPP	$5.00	LF	4,930	$24,650
4	Remove Concrete Lined Channel	$8.00	SY	29,964	$239,712
5	Sawcut Concrete	$1.50	LF	16,030	$24,045
6	Remove Gabion Baskets	$2.00	CY	4,100	$8,200
7	36" RCP	$85.00	LF	1,180	$100,300
8	Manholes	$2,500.00	EA	3	$7,500
9	Energy Dissipation Structure at 12th Street	$150,000.00	EA	1	$150,000
10	Grade Control Structures at RCBC	$30,000.00	EA	2	$60,000
11	Channel Excavation	$5.00	CY	22,454	$112,270
12	R & R sidewalk and landscaping	$10,000.00	LS	1	$10,000
13	Concrete Lined Channel (7")	$35.00	SY	33,123	$1,159,305
14	Concrete to Gabion Footing	$50.00	LF	10,000	$500,000
15	Wrought Iron Fence	$30.00	LF	1,900	$57,000
16	Reset Manhole Frame & Cover	$300.00	EA	13	$3,900
17	Remove Exst. Manhole	$500.00	EA	15	$7,500
18	Concrete Headwalls	$2,000.00	EA	5	$10,000
19	Bubble-up Grates	$1,500.00	EA	9	$13,500
20	15"-18" Pipe Extensions	$55.00	LF	200	$11,000
21	Gabion Baskets	$75.00	CY	4,100	$307,500
22	Utility Relocation's	$50,000.00	LS	1	$50,000
				SUBTOTAL	$3,070,982
		CONTINGENCIES:			
		Construction & Contingencies (%)		20	$614,196
		Engineering & CLOMR (%)		8	$245,679
		Construction Admin (%)		6	$184,259
				TOTAL	**$4,115,116**

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TABLE 2
Probable Construction Costs

November 4, 1997

GREENWAY PARKWAY CHANNEL
City of Phoenix

Index# ST-896829
W/P # 96559.00

CHANNEL ALTERNATIVE ANALYSIS
COST ANALYSIS, OPTION 3.9 w/RCP Replacement

DESCRIPTION: (DEEPEN CHANNEL) TRAPEZOIDAL SECTION BELOW GABION BASKETS, FULL 36" RCP REPLACEMENT

MAJOR ELEMENTS:

ITEM	DESCRIPTION	UNIT PRICE	UNIT	QUANTITY	AMOUNT
1	Mobilization (6.5% of Costruction)	$230,400.00	LS	1	$230,400
2	Traffic Control	$15,000.00	LS	1	$15,000
3	Remove 36" CIPP	$5.00	LF	4,930	$24,650
4	Remove Concrete Lined Channel	$8.00	SY	29,964	$239,712
5	Sawcut Concrete	$1.50	LF	16,030	$24,045
6	Remove Gabion Baskets	$2.00	CY	4,100	$8,200
7	36" RCP	$85.00	LF	4,930	$419,050
8	Manholes	$2,500.00	EA	10	$25,000
9	Energy Dissipation Structure at 12th Street	$150,000.00	EA	2	$300,000
10	Grade Control Structures at RCBC	$30,000.00	EA	1	$30,000
11	Channel Excavation	$5.00	CY	22,454	$112,270
12	R & R sidewalk and landscaping	$10,000.00	LS	1	$10,000
13	Concrete Lined Channel (7")	$35.00	SY	33,123	$1,159,305
14	Concrete to Gabion Footing	$50.00	LF	10,000	$500,000
14	Wrought Iron Fence	$30.00	LF	1,900	$57,000
15	Reset Manhole Frame & Cover	$300.00	EA	13	$3,900
16	Remove Exst. Manhole	$500.00	EA	15	$7,500
17	Concrete Headwalls	$2,000.00	EA	5	$10,000
18	15"-18" Pipe Extensions	$55.00	LF	200	$11,000
19	Gabion Baskets	$75.00	CY	4,100	$307,500
20	Utility Relocation's	$50,000.00	LS	1	$50,000
				SUBTOTAL	$3,544,532
		CONTINGENCIES:			
		Construction & Contingencies (%)		20	$708,906
		Engineering & CLOMR (%)		8	$283,563
		Construction Admin (%)		6	$212,672
				TOTAL	**$4,749,673**

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TABLE 3

Probable Construction Costs

Dibble's Recommended Option - Costs Updated to Include Upgrades

November 4, 1997

GREENWAY PARKWAY CHANNEL
City of Phoenix

Index# ST-896829
W/P # 96559.00

CHANNEL ALTERNATIVE ANALYSIS
COST ANALYSIS, OPTION 3.7

DESCRIPTION: RECONSTRUCT CHANNEL, SUPER CRITICAL SECTION

MAJOR ELEMENTS:

ITEM	DESCRIPTION	UNIT PRICE	UNIT	QUANTITY	AMOUNT
1	Mobilization (6.5% of Costruction)	$265,500.00	LS	1	$265,500
2	Traffic Control	$85,000.00	LS	1	$85,000
3	Remove 36" CIPP	$5.00	LF	2,196	$10,980
4	Remove Concrete Lined Channel	$8.00	SY	28,424	$227,392
5	Sawcut Concrete	$1.50	LF	4,000	$6,000
6	Remove Gabion Baskets	$2.00	CY	12,165	$24,330
7	Remove RCBC	$10,000.00	LS	2	$20,000
8	Fill Construction	$10.00	CY	12,560	$125,600
9	16th Street Bridge	$375,000.00	LS	1	$375,000
10	20th Street Bridge	$175,000.00	LS	1	$175,000
11	36" RCP	$85.00	LF	2,196	$186,660
12	Manholes	$2,500.00	EA	8	$20,000
13	Energy Dissipation Structure at 12th Street	$150,000.00	EA	1	$150,000
14	Channel Excavation	$5.00	CY	34,396	$171,980
15	R & R sidewalk and landscaping	$50,000.00	LS	1	$50,000
16	Concrete Lined Channel (7")	$35.00	SY	49,186	$1,721,510
17	Wrought Iron Fence	$30.00	LF	3,500	$105,000
18	Reset Manhole Frame & Cover	$300.00	EA	13	$3,900
19	Remove Exst. Manhole	$500.00	EA	8	$4,000
20	Concrete Headwalls	$2,000.00	EA	7	$14,000
21	Bubble-up Grates	$1,500.00	EA	9	$13,500
22	15"-18" Pipe Extensions	$55.00	LF	200	$11,000
23	Gabion Baskets	$75.00	CY	3,567	$267,525
24	Utility Relocation's	$50,000.00	LS	1	$50,000
				SUBTOTAL	$4,083,877
		CONTINGENCIES:			
		Construction & Contingencies (%)		20	$816,775
		Engineering & CLOMR (%)		8	$326,710
		Construction Admin (%)		6	$245,033
				TOTAL	**$5,472,395** *

* Cost does not include 20TH ST. Pedestrian Crossing R/W Constraint

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Exhibit 2

Existing Storm Drain Connections and
Summary of Existing vs. Proposed Channel Conditions

Greenway Parkway Channel
Channel Improvements for Recommended Option 3.9

Channel Station	Existing Channel Flowline	Existing Ground Elevation (Right)	Existing 36" CIPP Pipe Invert	Proposed Channel Flowline	Proposed CLOMR Water Surface Elev.	Proposed CLOMR Energy Grade Line	Proposed Difference in Flowline Elevation	Existing Channel Width (ft)	Proposed Channel Width (ft)	Proposed HGL Freeboard (ft)	Proposed EGL Freeboard (ft)	Proposed Velocity (ft/s)	Required Freeboard (based on Vel. - ft)	Froude #	Required Freeboard (based on Fr # - ft)	Analysis based on Velocity	Analysis based on Froude #
158+00	1377.99	1391.0		1377.99	1386.99	1391.59	0.00			4.0	-0.6	17.39	1.2	1.02	2	OK	OK
159+00	1378.69	1391.0	1370.00	1378.31	1388.43	1392.06	0.38	32	39	2.6	-1.1	15.47	1.0	0.86	2	OK	OK
161+00	1380.75	1393.0	1372.36	1378.94	1388.85	1392.90	1.81	32	39	4.2	0.1	16.28	1.5	0.92	2	OK	OK
164+00	1382.12	1394.0	1375.54	1379.89	1390.17	1394.01	2.23	32	39	3.8	0.0	15.83	1.5	0.88	2	OK	OK
166+00	1383.28	1394.2	1377.58	1380.53	1390.81	1394.78	2.75	32	39	3.4	-0.6	16.07	1.7	0.90	2	OK	OK
169+00	1385.02	1396.0	1379.28	1381.48	1391.87	1395.98	3.54	32	39	4.1	0.0	16.33	1.9	0.92	2	OK	OK
170+00	1385.43	1397.3	1379.75	1381.80	1392.62	1396.39	3.63	32	39	4.7	0.9	15.66	1.9	0.87	2	OK	OK
172+00	1386.24	1396.8	1380.70	1382.43	1393.32	1397.09	3.81	39	39	3.5	-0.3	15.65	1.9	0.87	2	OK	OK
174+00	1387.05	1397.8	1381.50	1383.06	1394.29	1397.78	3.99	39	39	3.5	0.0	15.07	1.9	0.82	1	OK	OK
179+00	1388.65	1399.5	1383.24	1383.93	1396.12	1399.20	4.72	39	39	3.4	0.3	14.14	2.0	0.75	1	OK	OK
182+00	1389.42	1401.0	1384.27	1384.45	1397.04	1399.96	4.97	39	39	4.0	1.0	13.77	2.0	0.72	1	OK	OK
183+00	1389.68	1401.2	1384.54	1384.63	1398.73	1400.25	5.05	39	39	2.5	1.0	9.91	1.6	0.48	1	OK	OK
184+00	1389.94	1401.1	1384.81	1384.80	1399.87	1400.40	5.14	39	39	1.2	0.7	5.82	1.4	0.27	1	Problem	OK
184+94	1390.13	1402.0	1385.07	1390.13	1401.42	1402.25	0.00	0		0.6	-0.3	7.36	0.2	0.39	1	OK	Problem
186+00	1390.69	1402.0	1385.35	1390.32	1399.79	1404.48	0.37	37	37	2.2	-2.5	17.51	1.3	1.01	2	OK	OK
188+60	1391.75	1404.0	1386.37	1390.79	1400.43	1405.06	0.96	37	37	3.6	-1.1	13.37	0.9	0.99	2	OK	OK
189+32	1392.09	1404.0	1386.67	1390.92	1403.46	1405.38	1.17	37	37	0.5	-1.4	11.22	0.8	0.56	1	Problem	Problem
193+12	1393.35	1406.0	1388.26	1391.61	1403.53	1405.63	1.74	37	37	2.5	0.4	11.77	1.0	0.61	1	OK	OK
193+60	1393.60	1406.5	1388.46	1391.70	1401.82	1407.32	1.90	37	37	4.7	-0.8	19.07	1.9	1.08	2	OK	OK
198+43	1396.05	1407.9	1389.46	1392.57	1403.99	1408.83	3.48	28	28	3.9	-0.9	17.85	2.1	0.97	2	OK	OK
203+60	1397.91	1410.4	1391.34	1393.50	1407.06	1409.59	4.41	28	28	3.3	0.8	12.92	1.8	0.65	1	OK	OK
208+60	1399.71	1412.5	1393.76	1394.40	1406.87	1410.34	5.31	28	28	5.6	2.2	15.07	2.2	0.82	1	OK	OK
213+00	1401.16	1413.9	1395.01	1395.19	1406.93	1411.51	5.97	28	28	7.0	2.4	17.20	2.6	0.99	2	OK	OK
214+00	1401.49	1413.3	1395.37	1395.37	1411.20	1411.93	6.12	28	28	2.1	1.4	6.88	1.7	0.34	1	OK	OK
214+70	1401.70	1413.0	1395.62	1401.70	1412.17	1413.02	0.00	0		0.8	0.0	7.45	0.2	0.41	1	OK	Problem
215+50	1401.95	1413.0	1395.90	1401.95	1411.48	1413.36		32	37	1.5	-0.4	11.09	0.5	0.63	1	OK	OK
218+50	1402.90	1413.2	1396.85	1402.90	1411.36	1413.76		32	37	1.8	-0.6	12.52	0.6	0.76	1	OK	OK
219+34	1403.14	1413.6	1397.08	1403.14	1412.43	1413.91		43	43	1.2	-0.3	9.80	0.4	0.57	1	OK	OK
223+50	1404.02	1414.2	1398.28	1404.02	1412.47	1414.26		43	43	1.7	-0.1	10.79	0.5	0.65	1	OK	OK
224+00	1404.15	1414.2	1398.43	1404.15	1411.59	1414.72		43	43	2.6	-0.5	14.27	0.8	0.92	2	OK	OK
228+50	1405.33	1415.0	1399.89	1405.33	1412.45	1415.87		37	37	2.5	-0.9	14.91	0.9	0.98	2	OK	OK
240+15	1409.80	1420.0	1403.33	1409.80	1413.24	1417.52		37	37	6.8	2.5	16.61	1.1	1.58	2	OK	OK

Exhibit 3

Calculation of Gabion Critical Velocity

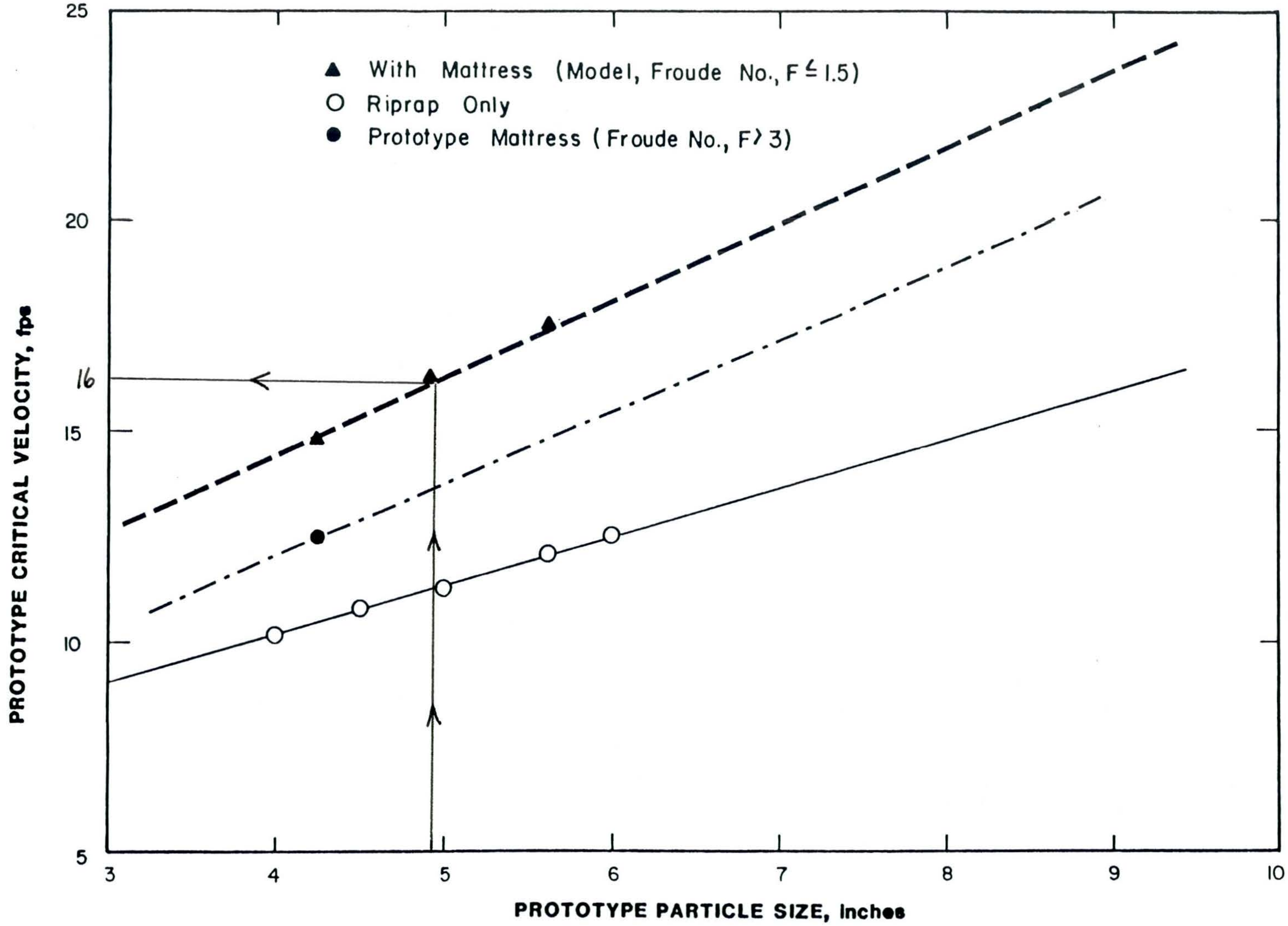


Figure 4.9. Critical velocity that initiates rock movement as a function of rock size.

REFERENCE 3

5. RIPRAP

There are different ways to prevent channel bottom and bank damage upstream and downstream from hydraulic structures, at bends, at bridges, and in other channel areas where erosive tendencies exist, but the primary method is by the use of riprap. One problem which the designer often neglects, however, is the "erosive" effect of neighborhood children in urban areas on the riprap itself. It has been found by many designers that the riprap is almost completely lost within the first month or two of project completion. It is usually thrown into the water by the children, purely for the sake of causing splashes. Increased police observance and meetings with neighborhood leaders have little effect. This non-hydraulic problem as to the use of riprap should keep the designer from choosing ordinary riprap in urban areas except for unusual cases, and then the material should be large.

In lieu of ordinary riprap the designer should consider grouted riprap or riprap enclosed in wire baskets, which is usually called gabions.

5.1 Ordinary Riprap

Many factors govern the size of the rock necessary to resist the forces tending to move the riprap. For the riprap itself this includes the size and weight of the individual rocks, the shape of the large pieces, the gradation of the mass, the thickness, the type of bedding under the riprap, and the slope of the riprap layer. Hydraulic forces affecting the riprap include the velocity, current direction, eddy action, and waves.

Experience has shown that the usual cause of riprap failure is undersized individual rocks in the maximum size range. Failure has occurred because of the rocks being undersized, and a general tendency of contractors to put in riprap which is smaller than specified.

It has been established that a well graded riprap layer containing about 40 percent of the rock pieces smaller than the required size is as stable or more stable than individual rocks of the required size. This is probably due to the interlocking benefits of graded riprap.

5.1.1 Design. Field experience has shown that a riprap layer to work most effectively should be about one and one-half times or more as thick as the dimension of the large rocks and that the riprap should be placed over a gravel layer. Figure 5-1 shows the relationship between bottom velocity and rock diameter (13). In referring to the figure, bottom velocity can be taken as approximately 0.7 times the mean channel velocity.

5.2 Gabions

Gabions, in addition to being more resistant to vandalism, provide a dependable erosion-resistant bank or bottom and permit the use of smaller

REFERENCE 12

Example 2-1. Compute the hydraulic radius, hydraulic depth, and section factor Z of the trapezoidal channel section in Fig. 2-2. The depth of flow is 6 ft.

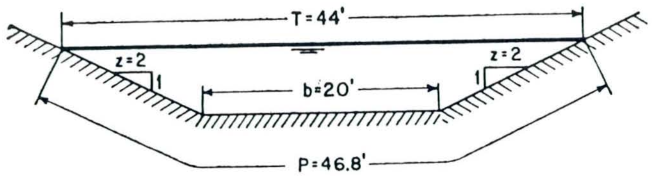


FIG. 2-2. A channel cross section.

Solution. By formulas given in Table 2-1, the following are computed: $P = 20 + 2 \times 6 \sqrt{5} = 46.8$ ft; $A = 0.5(20 + 44) \times 6 = 192.0$ ft^2; $R = 192/46.8 = 4.10$ ft; $D = {}^{192}\!/_{44} = 4.37$ ft; and $Z = 192 \sqrt{4.37} = 401$ ft$^{2.5}$.

2-4. Velocity Distribution in a Channel Section. Owing to the presence of a free surface and to the friction along the channel wall, the velocities in a channel are not uniformly distributed in the channel section. The measured maximum velocity in ordinary channels usually appears to occur below the free surface at a distance of 0.05 to 0.25 of the depth; the closer to the banks, the deeper is the maximum. Figure 2-3 illustrates the general pattern of velocity distribution over various vertical and horizontal sections of a rectangular channel section and the curves of equal velocity in the cross section. The general patterns for velocity distribution in several channel sections of other shapes are illustrated in Fig. 2-4.

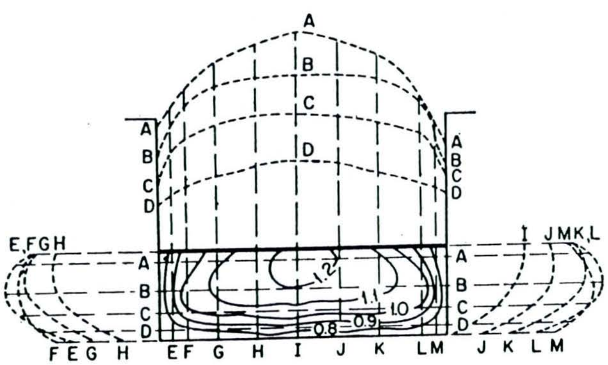


FIG. 2-3. Velocity distribution in a rectangular channel.

The velocity distribution in a channel section depends also on other factors, such as the unusual shape of the section, the roughness of the

(Reference 2)

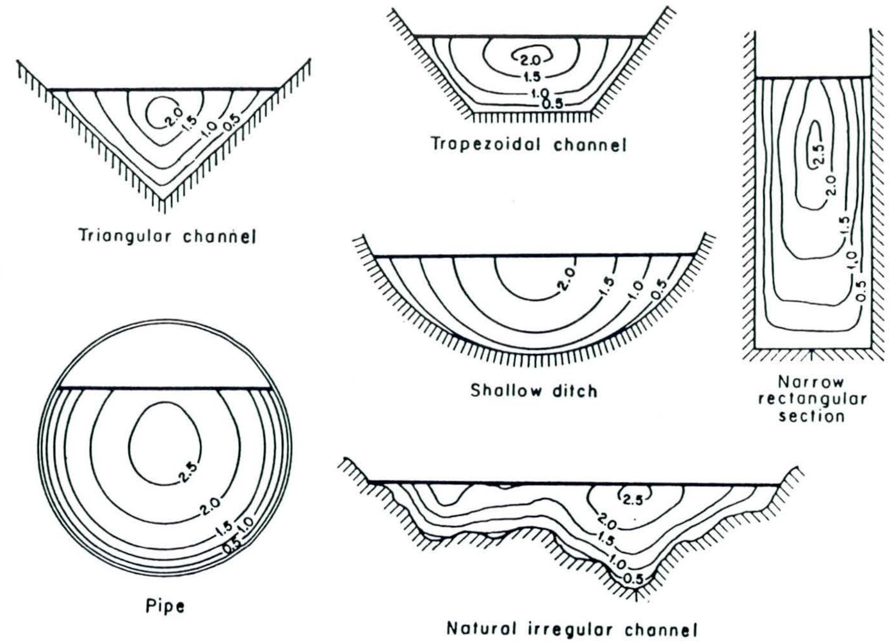


FIG. 2-4. Typical curves of equal velocity in various channel sections.

channel, and the presence of bends. In a broad, rapid, and shallow stream or in a very smooth channel, the maximum velocity may often be found at the free surface. The roughness of the channel will cause the curvature of the vertical-velocity-distribution curve to increase (Fig. 2-5). On a bend the velocity increases greatly at the convex side, owing to the centrifugal action of the flow. Contrary to the usual belief, a surface wind has very little effect on velocity distribution.

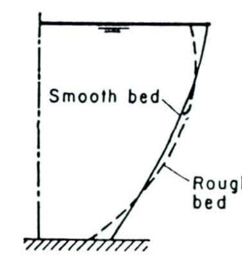


FIG. 2-5: Effect of roughness on velocity distribution in an open channel.

As revealed by careful laboratory investigations, the flow in a straight prismatic channel is in fact three-dimensional, manifesting a spiral motion, although the velocity component in the transverse channel section is usually small and insignificant compared with the longitudinal velocity components. Shukry [6] found that, in short laboratory flumes, a small disturbance at the entrance, which is usually unavoidable, is sufficient to cause the zone of highest water level to shift to one side, thus giving rise to a single spiral motion (Fig. 2-6). In a long and uniform reach remote from the entrance, a double spiral motion will occur to permit equalization of shear stresses on both sides of the channel [7,8].

If the designer has no knowledge of the erodibility of the soil at a particular channel site, a reasonable estimate of d_{max} may be obtained by interpolating half-way between the "erosion resistant" and "erodible" lines of the maximum permissible depth charts (except Chart 27 for rock riprap, where no range is given because the underlying soil has no influence on the erosion resistance of the riprap lining).

Hydraulic Resistance

The flow velocity charts were developed to define the relationship between the hydraulic radius of the channel, R, longitudinal slope of the channel, S_o, and mean channel velocity, V, for a given channel lining. For some linings, such as rock riprap of a given size and fiber glass roving tacked with asphalt, the Manning equation may be used since the n value is essentially constant. For rock riprap, the Manning n value varies with mean stone size, as follows (6):

$$n = 0.0395\ D_{50}^{1/6}$$

Thus, the following n values apply for common stone sizes:

D_{50} (ft.)	n
0.25	0.0314
0.50	0.0352
0.75	0.0377
1.00	0.0395
1.50	0.0423
2.00	0.0443

For fiber glass roving tacked with asphalt, Cox (4) found that the Manning n value was approximately a constant:

	Smooth Rolled Channels	Channels with Clods and Tracks
Single layer	0.030	0.035
Double layer	0.020	0.025

The higher values of n were used in the development of Charts 5 and 6, assuming that most highway channels will be rather rough after seeding and mulching.

(Reference 12)

Table 6.11
Manning's Roughness Coefficients [1]

Channel Material	Roughness Coefficient (n)		
	Minimum	**Normal**	**Maximum**
Corrugated metal	0.021	0.025	0.030
Concrete:			
Trowel finish	0.011	0.013	0.015
Float finish	0.013	0.015	0.016
Unfinished	0.014	0.017	0.020
Shotcrete, good section	0.016	0.019	0.023
Shotcrete, wavy section	0.018	0.022	0.025
Asphalt [2]	0.013	0.016	0.020
Soil cement	0.018	0.020	0.025
Constructed channels with earth or sand bottom			
Clean earth; straight	0.018	0.022	0.025
Earth with grass and weeds	0.020	0.025	0.030
Earth with trees and shrubs	0.024	0.032	0.040
Shotcrete	0.018	0.022	0.025
Soil cement	0.022	0.025	0.028
Concrete	0.017	0.020	0.024
Riprap	0.023	0.032	0.036
Natural channels with sand bottom and sides of:			
Trees and shrubs	0.025	0.035	0.045
Rock	0.024	0.032	0.040
Natural channel with rock bottom	0.040	0.060	0.090
Overbank floodplains:			
Desert brush, normal density	0.040	0.060	0.080
Dense vegetation	0.070	0.100	0.160

(1) From: Simons, Li and Associates, 1988. Adapted from Chow (1959) and Aldridge and Garret (1973).

(2) Use maximum value when cars are present.

(REFERENCE 5)

TABLE 5-6. VALUES OF THE ROUGHNESS COEFFICIENT n
(Boldface figures are values generally recommended in design)

Type of channel and description	Minimum	Normal	Maximum
A. CLOSED CONDUITS FLOWING PARTLY FULL			
A-1. Metal			
a. Brass, smooth	0.009	**0.010**	0.013
b. Steel			
1. Lockbar and welded	0.010	0.012	0.014
2. Riveted and spiral	0.013	0.016	0.017
c. Cast iron			
1. Coated	0.010	0.013	0.014
2. Uncoated	0.011	0.014	0.016
d. Wrought iron			
1. Black	0.012	**0.014**	0.015
2. Galvanized	0.013	**0.016**	0.017
e. Corrugated metal			
1. Subdrain	0.017	0.019	0.021
2. Storm drain	0.021	**0.024**	0.030
A-2. Nonmetal			
a. Lucite	0.008	0.009	0.010
b. Glass	0.009	**0.010**	0.013
c. Cement			
1. Neat, surface	0.010	0.011	0.013
2. Mortar	0.011	0.013	0.015
d. Concrete			
1. Culvert, straight and free of debris	0.010	0.011	0.013
2. Culvert with bends, connections, and some debris	0.011	**0.013**	0.014
3. Finished	0.011	0.012	0.014
4. Sewer with manholes, inlet, etc., straight	0.013	0.015	0.017
5. Unfinished, steel form	0.012	0.013	0.014
6. Unfinished, smooth wood form	0.012	**0.014**	0.016
7. Unfinished, rough wood form	0.015	0.017	0.020
e. Wood			
1. Stave	0.010	0.012	0.014
2. Laminated, treated	0.015	0.017	0.020
f. Clay			
1. Common drainage tile	0.011	**0.013**	0.017
2. Vitrified sewer	0.011	0.014	0.017
3. Vitrified sewer with manholes, inlet, etc.	0.013	0.015	0.017
4. Vitrified subdrain with open joint	0.014	**0.016**	0.018
g. Brickwork			
1. Glazed	0.011	**0.013**	0.015
2. Lined with cement mortar	0.012	**0.015**	0.017
h. Sanitary sewers coated with sewage slimes, with bends and connections	0.012	0.013	0.016
i. Paved invert, sewer, smooth bottom	0.016	0.019	0.020
j. Rubble masonry, cemented	0.018	0.025	0.030

(REFERENCE 2)

TABLE 5-6. VALUES OF THE ROUGHNESS COEFFICIENT n (*continued*)

Type of channel and description	Minimum	Normal	Maximum
B. LINED OR BUILT-UP CHANNELS			
B-1. Metal			
a. Smooth steel surface			
1. Unpainted	0.011	**0.012**	0.014
2. Painted	0.012	0.013	0.017
b. Corrugated	0.021	0.025	0.030
B-2. Nonmetal			
a. Cement			
1. Neat, surface	0.010	0.011	0.013
2. Mortar	0.011	0.013	0.015
b. Wood			
1. Planed, untreated	0.010	0.012	0.014
2. Planed, creosoted	0.011	0.012	0.015
3. Unplaned	0.011	0.013	0.015
4. Plank with battens	0.012	0.015	0.018
5. Lined with roofing paper	0.010	0.014	0.017
c. Concrete			
1. Trowel finish	0.011	**0.013**	0.015
→ 2. Float finish	0.013	0.015	0.016
3. Finished, with gravel on bottom	0.015	0.017	0.020
4. Unfinished	0.014	0.017	0.020
5. Gunite, good section	0.016	0.019	0.023
6. Gunite, wavy section	0.018	0.022	0.025
7. On good excavated rock	0.017	0.020	
8. On irregular excavated rock	0.022	0.027	
d. Concrete bottom float finished with sides of			
1. Dressed stone in mortar	0.015	0.017	0.020
2. Random stone in mortar	0.017	0.020	0.024
3. Cement rubble masonry, plastered	0.016	0.020	0.024
4. Cement rubble masonry	0.020	0.025	0.030
5. Dry rubble or riprap	0.020	0.030	0.035
e. Gravel bottom with sides of			
1. Formed concrete	0.017	0.020	0.025
2. Random stone in mortar	0.020	0.023	0.026
3. Dry rubble or riprap	0.023	0.033	0.036
f. Brick			
1. Glazed	0.011	**0.013**	0.015
2. In cement mortar	0.012	**0.015**	0.018
g. Masonry			
1. Cemented rubble	0.017	0.025	0.030
2. Dry rubble	0.023	0.032	0.035
h. Dressed ashlar	0.013	0.015	0.017
i. Asphalt			
1. Smooth	0.013	0.013	
2. Rough	0.016	0.016	
j. Vegetal lining	0.030	.....	0.500

≈0.025

Exhibit 4

Photographs

Location of Proposed Energy Dissipating Structure near 12th Street
Looking Upstream

Location of Proposed Energy Dissipating Structure near 12th Street
Looking Downstream

Downstream End of 16th Street RCBC
Note Existing Manhole & 84" Storm Drain Outlet

Looking Upstream of the 16th Street RCBC
Note Channel Widening Near RCBC, Exist Gabions & Enhanced Vegetation at Banks

Upstream End of 20th Street RCBC
Note Height of Headwall

Downstream end of 20th Street RCBC
Note 84" Storm Drain Outlet

Looking Downstream of the 20th Street RCBC
Note Narrowing of Channel D/S of RCBC & Pedestrian Overpass Footing

Beginning of Greenway Parkway Channel Looking East
Note Grate in Bottom of Channel. It is Partially Removed from the Frame

Exhibit 5

HEC-RAS Model Results, 10-Year Proposed Condition

Wood, Patel and Associates

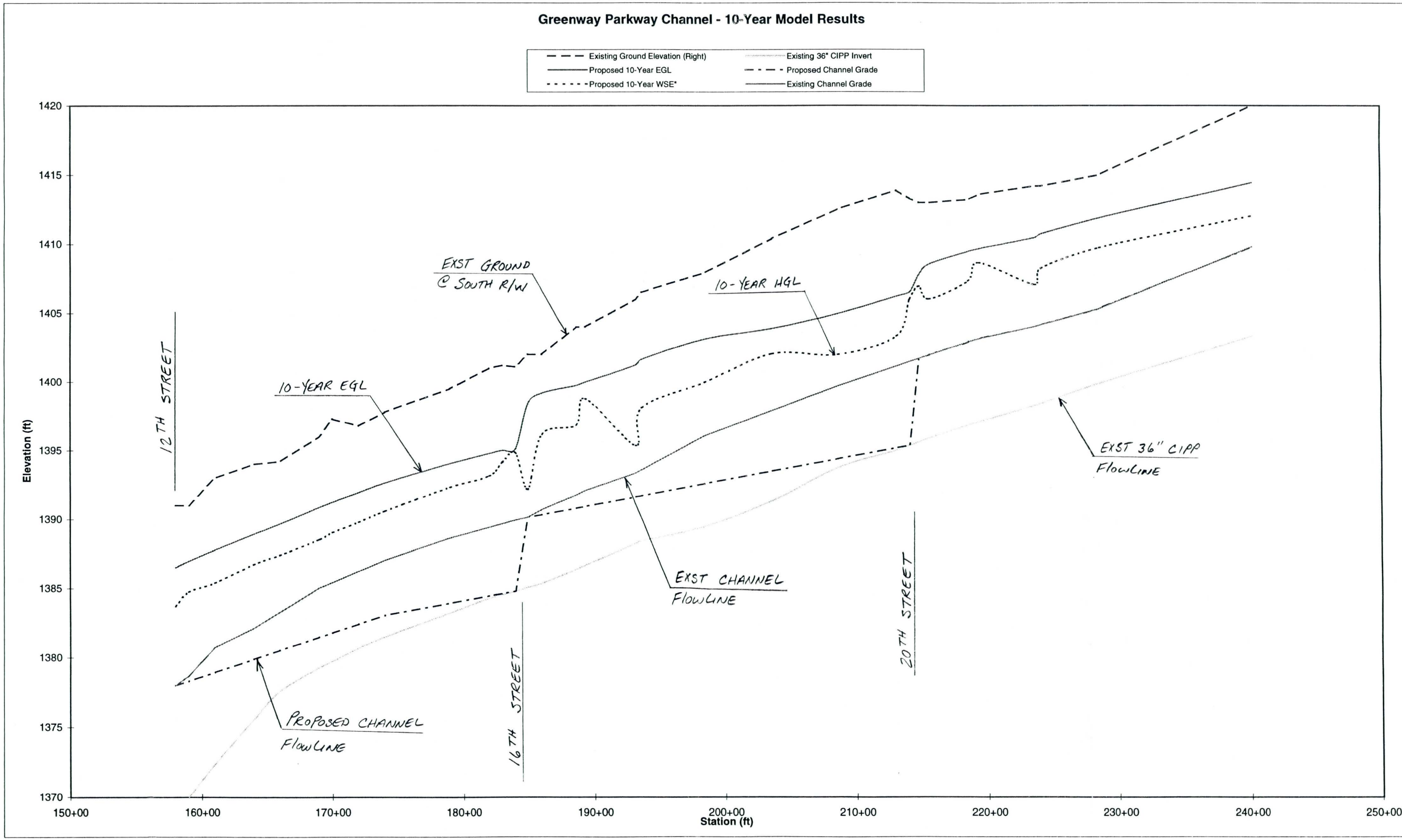
Greenway Parkway Channel
10-Year Flow Rates with the Improved Channel (Recommended Option 3.9)

Reach	River Sta	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
		(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
Greenway	24015	1000	1409.80	1412.04	1412.68	1414.44	0.005404	12.45	80.46	36.05	1.47
Greenway	23917.9*	1000	1409.43	1411.92	1412.31	1413.85	0.004091	11.14	89.84	36.15	1.24
Greenway	23820.8*	1000	1409.06	1411.60	1411.93	1413.45	0.003825	10.91	91.79	36.23	1.21
Greenway	23723.7*	1000	1408.68	1411.24	1411.55	1413.05	0.003726	10.81	92.62	36.31	1.19
Greenway	23626.6*	1000	1408.31	1411.72		1412.73	0.001432	8.07	125.60	40.27	0.77
Greenway	23529.5*	1000	1407.94	1411.75		1412.55	0.000980	7.19	142.10	40.37	0.65
Greenway	23432.5*	1000	1407.57	1411.78		1412.43	0.000702	6.50	158.25	40.48	0.56
Greenway	23335.4*	1000	1407.19	1411.80		1412.34	0.000515	5.91	174.82	40.59	0.49
Greenway	23238.3*	1000	1406.82	1411.81		1412.27	0.000392	5.44	190.83	40.69	0.43
Greenway	23141.2*	1000	1406.45	1411.82		1412.21	0.000304	5.04	206.88	40.80	0.38
Greenway	23044.1*	1000	1406.07	1411.83		1412.17	0.000239	4.68	223.36	40.92	0.34
Greenway	22947.0*	1000	1405.70	1411.84		1412.14	0.000193	4.38	239.87	44.85	0.31
Greenway	22850	1925	1405.33	1409.73	1409.73	1411.89	0.001969	11.81	168.42	40.99	0.99
Greenway	22760.*	1925	1405.09	1409.22	1409.49	1411.66	0.002678	12.55	157.46	40.98	1.09
Greenway	22670.*	1925	1404.86	1408.98	1409.26	1411.43	0.002703	12.58	157.00	40.97	1.09
Greenway	22580.*	1925	1404.62	1408.74	1409.02	1411.20	0.002710	12.59	156.87	40.97	1.09
Greenway	22490.*	1925	1404.39	1408.50	1408.79	1410.97	0.002741	12.64	156.30	40.97	1.10
Greenway	22400	1925	1404.15	1408.25	1408.55	1410.74	0.002505	12.70	155.93	40.97	1.11
Greenway	22350	1925	1404.02	1407.05	1408.00	1410.46	0.005114	14.82	130.26	46.90	1.50
Greenway	22266.7*	1925	1403.84	1408.78		1410.04	0.001080	9.03	219.95	47.03	0.72
Greenway	22183.4*	1925	1403.67	1408.73		1409.93	0.000991	8.80	225.98	47.04	0.69
Greenway	22100.1*	1925	1403.49	1408.70		1409.83	0.000899	8.55	232.99	47.05	0.66
Greenway	22016.8*	1925	1403.32	1408.67		1409.74	0.000823	8.32	239.54	47.06	0.63
Greenway	21933.6	1925	1403.14	1408.65		1409.66	0.000688	8.11	246.88	47.07	0.61
Greenway	21850	1925	1402.90	1407.30	1407.30	1409.46	0.001973	11.81	168.33	40.99	0.99
Greenway	21750.*	1925	1402.58	1406.61	1406.98	1409.18	0.002921	12.88	153.14	40.97	1.13
Greenway	21650.*	1925	1402.27	1406.52	1406.67	1408.82	0.002446	12.21	162.09	40.98	1.04
Greenway	21550	1925	1401.95	1406.02	1406.35	1408.55	0.002558	12.78	154.88	40.97	1.12
Greenway	21470	1925	1401.70	1406.93	1405.31	1407.76	0.000604	7.33	272.68	55.05	0.57
Greenway	21435	Culvert									
Greenway	21400	2201	1395.37	1406.03		1406.53	0.000244	5.66	394.57	55.00	0.36
Greenway	21300	2201	1395.19	1403.33	1403.33	1406.23	0.002269	13.68	160.84	28.09	1.01
Greenway	21212.*	2201	1395.03	1402.82	1403.07	1406.00	0.002630	14.32	153.74	28.09	1.08
Greenway	21124.*	2201	1394.87	1402.67	1402.83	1405.74	0.002468	14.06	156.55	28.10	1.05
Greenway	21036.*	2201	1394.72	1402.56	1402.65	1405.48	0.002261	13.70	162.29	31.93	1.01
Greenway	20948.*	2201	1394.56	1402.07	1402.40	1405.24	0.002598	14.30	156.32	31.95	1.08
Greenway	20860	2201	1394.40	1401.99	1402.14	1404.96	0.002331	13.84	163.37	31.99	1.03
Greenway	20760.*	2201	1394.22	1401.50	1401.84	1404.69	0.002611	14.34	157.39	31.98	1.08
Greenway	20660.*	2201	1394.04	1402.06		1404.42	0.001595	12.37	184.83	32.04	0.87
Greenway	20560.*	2201	1393.86	1402.05		1404.21	0.001372	11.84	194.03	32.06	0.81
Greenway	20460.*	2201	1393.68	1402.05		1404.03	0.001186	11.34	203.35	32.09	0.76
Greenway	20360	2201	1393.50	1402.04		1403.88	0.001038	10.91	212.89	35.91	0.72
Greenway	20273.8*	2201	1393.34	1402.05		1403.75	0.000918	10.53	222.39	35.93	0.68
Greenway	20187.7*	2201	1393.19	1402.05		1403.65	0.000820	10.18	231.55	35.95	0.65
Greenway	20101.6*	2201	1393.03	1402.06		1403.55	0.000733	9.85	240.87	35.97	0.62
Greenway	20015.5*	2201	1392.88	1402.06		1403.46	0.000661	9.55	249.80	35.99	0.59
Greenway	19929.4*	2201	1392.72	1402.07		1403.38	0.000596	9.27	259.01	36.01	0.57
Greenway	19843.3	2612	1392.57	1399.96	1399.96	1403.11	0.001987	14.29	192.40	32.09	0.99
Greenway	19746.6*	2612	1392.40	1399.19	1399.71	1402.85	0.002535	15.42	178.10	32.08	1.11
Greenway	19649.9*	2612	1392.22	1399.25	1399.40	1402.49	0.002057	14.51	191.45	35.91	1.02
Greenway	19553.3*	2612	1392.05	1398.66	1399.12	1402.24	0.002401	15.24	182.18	35.91	1.09
Greenway	19456.6*	2612	1391.87	1398.78	1398.82	1401.89	0.001909	14.24	198.12	35.95	0.99
Greenway	19360	2612	1391.70	1398.11	1398.53	1401.65	0.002348	15.19	185.41	35.93	1.09
Greenway	19311.9	2612	1391.61	1395.36	1397.09	1401.22	0.007757	19.47	137.42	41.97	1.83
Greenway	19216.9*	2612	1391.44	1398.83		1400.20	0.000700	9.45	294.92	45.36	0.62
Greenway	19121.9*	2612	1391.27	1398.81		1400.12	0.000649	9.25	299.20	44.72	0.60
Greenway	19026.9*	2612	1391.09	1398.78		1400.05	0.000600	9.05	304.38	46.89	0.58
Greenway	18931.9	2612	1390.92	1398.77		1399.98	0.000554	8.85	310.51	45.95	0.56
Greenway	18860	2612	1390.79	1396.85	1396.85	1399.74	0.001887	13.67	198.39	36.04	0.99
Greenway	18773.3*	2612	1390.63	1396.48	1396.66	1399.55	0.002084	14.10	192.49	36.04	1.04
Greenway	18686.6*	2612	1390.48	1396.33	1396.47	1399.37	0.002044	14.04	194.02	36.05	1.03
Greenway	18600	2612	1390.32	1396.17	1396.29	1399.18	0.002003	13.97	195.63	36.07	1.02
Greenway	18493.5	2612	1390.13	1392.17	1393.85	1398.39	0.015752	20.01	130.65	64.04	2.47
Greenway	18446.75	Culvert									
Greenway	18400	2612	1384.80	1394.82		1395.12	0.000311	4.42	597.20	68.03	0.26
Greenway	18300	2995	1384.63	1394.14		1395.01	0.001028	7.50	404.44	51.00	0.45
Greenway	18200	2995	1384.45	1393.13		1394.78	0.002352	10.30	293.16	42.95	0.67
Greenway	18100.*	2995	1384.28	1392.87		1394.54	0.002403	10.38	291.15	42.95	0.67
Greenway	18000.*	2995	1384.10	1392.60		1394.30	0.002463	10.46	288.85	42.95	0.68
Greenway	17900	2995	1383.93	1392.31		1394.05	0.002555	10.58	285.48	42.94	0.69
Greenway	17800.*	2995	1383.76	1392.03		1393.79	0.002604	10.65	283.76	42.95	0.70
Greenway	17700.*	2995	1383.58	1391.75		1393.53	0.002653	10.72	282.10	42.95	0.71
Greenway	17600.*	2995	1383.41	1391.42		1393.26	0.002775	10.87	278.08	42.95	0.72
Greenway	17500.*	2995	1383.23	1391.06		1392.96	0.002939	11.07	273.05	42.95	0.74
Greenway	17400	2995	1383.06	1390.59		1392.64	0.003308	11.48	262.85	42.94	0.78
Greenway	17300.*	2995	1382.75	1390.28		1392.30	0.003253	11.43	264.33	42.94	0.78
Greenway	17200	3028	1382.43	1389.79		1391.95	0.003547	11.78	258.92	42.94	0.81
Greenway	17100.*	3028	1382.11	1389.44		1391.59	0.003551	11.80	258.88	42.94	0.81

Greenway Parkway Channel
10-Year Flow Rates with the Improved Channel (Recommended Option 3.9)

Reach	River Sta	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
		(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
Greenway	17000	3028	1381.80	1389.05		1391.24	0.003626	11.88	257.23	42.94	0.82
Greenway	16900	3028	1381.48	1388.53		1390.85	0.003970	12.22	249.79	42.93	0.85
Greenway	16800.*	3028	1381.16	1388.15		1390.45	0.003898	12.17	251.51	42.95	0.85
Greenway	16700.*	3028	1380.85	1387.77		1390.06	0.003855	12.14	252.67	42.96	0.85
Greenway	16600	3028	1380.53	1387.41		1389.67	0.003778	12.08	254.56	42.98	0.84
Greenway	16500.*	3028	1380.21	1387.06		1389.29	0.003676	12.00	257.07	42.99	0.83
Greenway	16400	3028	1379.89	1386.73		1388.92	0.003553	11.89	260.16	43.01	0.82
Greenway	16300.*	3028	1379.57	1386.38		1388.56	0.003537	11.88	260.69	43.01	0.82
Greenway	16200.*	3028	1379.26	1385.96		1388.20	0.003669	12.02	257.83	43.02	0.84
Greenway	16100	3028	1378.94	1385.39		1387.79	0.004125	12.46	248.52	43.01	0.88
Greenway	16000.*	3028	1378.63	1385.06		1387.37	0.003833	12.23	255.32	43.06	0.86
Greenway	15900	3028	1378.31	1384.74		1386.98	0.003626	12.07	261.28	46.90	0.84
Greenway	15800	3028	1377.99	1383.71	1383.71	1386.51	0.005035	13.49	233.85	43.08	0.99

Greenway Parkway Channel



Q:\Greenway\Existing vertical.xls; Graph-> 10-Year
11/3/97; 3:19 PM

Exhibit 6

HEC-RAS Model Results, Proposed Condition

Wood, Patel and Associates

Greenway Parkway Channel
CLOMR Flow Rates with the Improved Channel (Recommended Option 3.9)

Reach	River Sta	Q Total (cfs)	Min Ch El (ft)	W.S. Elev (ft)	Crit W.S. (ft)	E.G. Elev (ft)	E.G. Slope (ft/ft)	Vel Chnl (ft/s)	Flow Area (sq ft)	Top Width (ft)	Froude # Chl
Greenway	24015	2056	1409.80	1413.24	1414.48	1417.52	0.005408	16.61	125.71	39.93	1.58
Greenway	23917.9*	2056	1409.43	1415.53		1416.86	0.000876	9.29	232.78	44.00	0.66
Greenway	23820.8*	2056	1409.06	1415.57		1416.73	0.000697	8.66	251.62	44.16	0.60
Greenway	23723.7*	2056	1408.68	1415.61		1416.62	0.000561	8.10	270.84	44.33	0.54
Greenway	23626.6*	2056	1408.31	1415.65		1416.54	0.000461	7.63	289.29	44.44	0.50
Greenway	23529.5*	2056	1407.94	1415.67		1416.47	0.000384	7.21	307.50	44.52	0.46
Greenway	23432.5*	2056	1407.57	1415.69		1416.41	0.000324	6.84	325.60	44.60	0.42
Greenway	23335.4*	2056	1407.19	1415.71		1416.36	0.000274	6.50	344.14	44.68	0.39
Greenway	23238.3*	2056	1406.82	1415.73		1416.32	0.000235	6.20	362.12	44.76	0.37
Greenway	23141.2*	2056	1406.45	1415.74		1416.28	0.000203	5.92	380.16	44.84	0.34
Greenway	23044.1*	2056	1406.07	1415.76		1416.25	0.000175	5.67	398.72	44.94	0.32
Greenway	22947.0*	2056	1405.70	1415.77		1416.22	0.000153	5.44	416.67	45.02	0.30
Greenway	22850	3957	1405.33	1412.45	1412.45	1415.87	0.001654	14.91	284.53	45.10	0.98
Greenway	22760.*	3957	1405.09	1411.74	1412.20	1415.66	0.002298	15.96	263.08	45.03	1.09
Greenway	22670.*	3957	1404.86	1411.63	1411.97	1415.40	0.002156	15.65	268.80	45.05	1.06
Greenway	22580.*	3957	1404.62	1411.61	1411.73	1415.14	0.001942	15.16	278.35	45.10	1.01
Greenway	22490.*	3957	1404.39	1411.60	1411.50	1414.91	0.001744	14.68	288.50	45.10	0.96
Greenway	22400	3957	1404.15	1411.59		1414.72	0.001430	14.27	298.70	45.10	0.92
Greenway	22350	3957	1404.02	1412.47		1414.26	0.000689	10.79	395.09	51.06	0.65
Greenway	22266.7*	3957	1403.84	1412.48		1414.18	0.000695	10.52	404.55	51.08	0.63
Greenway	22183.4*	3957	1403.67	1412.47		1414.10	0.000654	10.33	412.55	51.09	0.61
Greenway	22100.1*	3957	1403.49	1412.46		1414.03	0.000613	10.13	421.33	51.10	0.60
Greenway	22016.8*	3957	1403.32	1412.45		1413.96	0.000578	9.95	429.47	51.10	0.58
Greenway	21933.6	3957	1403.14	1412.43		1413.91	0.000501	9.80	438.00	51.10	0.57
Greenway	21850	3957	1402.90	1411.36		1413.76	0.000927	12.52	344.48	45.06	0.76
Greenway	21750.*	3957	1402.58	1411.43		1413.60	0.000875	11.91	362.08	45.09	0.71
Greenway	21650.*	3957	1402.27	1411.45		1413.47	0.000773	11.48	377.98	48.94	0.67
Greenway	21550	3957	1401.95	1411.48		1413.36	0.000620	11.09	395.01	49.01	0.63
Greenway	21470	3957	1401.70	1412.17	1407.50	1413.02	0.000247	7.45	584.93	63.10	0.41
Greenway	21435	Culvert									
Greenway	21400	4525	1395.37	1411.20		1411.93	0.000181	6.88	696.64	63.04	0.34
Greenway	21300	4525	1395.19	1406.93	1406.93	1411.51	0.001868	17.20	273.02	32.08	0.99
Greenway	21212.*	4525	1395.03	1406.18	1406.77	1411.28	0.002232	18.15	258.84	32.07	1.08
Greenway	21124.*	4525	1394.87	1406.66	1406.50	1410.97	0.001695	16.71	287.49	35.96	0.95
Greenway	21036.*	4525	1394.72	1406.75		1410.73	0.001496	16.09	302.99	36.01	0.90
Greenway	20948.*	4525	1394.56	1406.83		1410.51	0.001330	15.52	318.14	36.06	0.86
Greenway	20860	4525	1394.40	1406.87		1410.34	0.001204	15.07	332.64	39.93	0.82
Greenway	20760.*	4525	1394.22	1406.92		1410.15	0.001071	14.55	347.33	40.01	0.78
Greenway	20660.*	4525	1394.04	1406.97		1409.98	0.000959	14.09	361.61	40.10	0.74
Greenway	20560.*	4525	1393.86	1407.00		1409.84	0.000865	13.67	375.42	40.10	0.71
Greenway	20460.*	4525	1393.68	1407.03		1409.71	0.000784	13.28	389.01	40.10	0.68
Greenway	20360	4525	1393.50	1407.06		1409.59	0.000714	12.92	402.34	40.10	0.65
Greenway	20273.8*	4525	1393.34	1407.08		1409.49	0.000660	12.62	413.77	40.10	0.63
Greenway	20187.7*	4525	1393.19	1407.10		1409.41	0.000613	12.36	424.78	40.10	0.61
Greenway	20101.6*	4525	1393.03	1407.12		1409.33	0.000570	12.10	435.88	40.10	0.59
Greenway	20015.5*	4525	1392.88	1407.13		1409.25	0.000532	11.86	446.54	40.10	0.58
Greenway	19929.4*	4525	1392.72	1407.15		1409.18	0.000497	11.63	457.43	40.10	0.56
Greenway	19843.3	5371	1392.57	1403.99	1403.99	1408.83	0.001621	17.85	340.84	40.09	0.97
Greenway	19746.6*	5371	1392.40	1402.97	1403.66	1408.58	0.002044	19.20	314.37	39.98	1.08
Greenway	19649.9*	5371	1392.22	1403.32	1403.32	1408.17	0.001619	17.91	342.71	40.10	0.98
Greenway	19553.3*	5371	1392.05	1402.38	1403.03	1407.93	0.001999	19.14	318.95	40.06	1.08
Greenway	19456.6*	5371	1391.87	1402.70	1402.71	1407.55	0.001603	17.92	346.01	40.10	0.98
Greenway	19360	5371	1391.70	1401.82	1402.40	1407.32	0.001955	19.07	323.94	40.10	1.08
Greenway	19311.9	5371	1391.61	1403.53		1405.63	0.000569	11.77	518.35	50.10	0.61
Greenway	19216.9*	5371	1391.44	1403.51		1405.56	0.000542	11.62	520.93	49.10	0.59
Greenway	19121.9*	5371	1391.27	1403.49		1405.50	0.000518	11.49	522.90	48.10	0.58
Greenway	19026.9*	5371	1391.09	1403.47		1405.44	0.000494	11.34	524.99	47.10	0.57
Greenway	18931.9	5371	1390.92	1403.46		1405.38	0.000473	11.22	526.44	46.10	0.56
Greenway	18860	5371	1390.79	1400.43	1400.43	1405.06	0.001622	17.37	338.09	40.08	0.99
Greenway	18773.3*	5371	1390.63	1399.91	1400.26	1404.88	0.001821	18.01	325.89	40.07	1.05
Greenway	18686.6*	5371	1390.48	1399.84	1400.08	1404.68	0.001741	17.79	331.55	40.09	1.03
Greenway	18600	5371	1390.32	1399.79	1399.87	1404.48	0.001649	17.51	338.33	40.10	1.01
Greenway	18493.5	5371	1390.13	1401.42	1396.13	1402.25	0.000218	7.36	786.42	76.10	0.39
Greenway	18446.75	Culvert									
Greenway	18400	5371	1384.80	1399.87		1400.40	0.000301	5.82	960.77	76.09	0.27
Greenway	18300	6157	1384.63	1398.73		1400.25	0.001008	9.91	651.42	58.91	0.48
Greenway	18200	6157	1384.45	1397.04		1399.96	0.002391	13.77	467.55	47.01	0.72
Greenway	18100.*	6157	1384.28	1396.75		1399.71	0.002443	13.87	464.27	47.01	0.73
Greenway	18000.*	6157	1384.10	1396.45		1399.46	0.002505	13.98	460.47	47.00	0.74
Greenway	17900	6157	1383.93	1396.12		1399.20	0.002597	14.14	455.02	47.00	0.75
Greenway	17800.*	6157	1383.76	1395.83		1398.94	0.002635	14.21	452.99	47.00	0.76
Greenway	17700.*	6157	1383.58	1395.54		1398.67	0.002670	14.27	451.14	47.00	0.76
Greenway	17600.*	6157	1383.41	1395.19		1398.40	0.002765	14.44	446.02	47.00	0.77
Greenway	17500.*	6157	1383.23	1394.81		1398.10	0.002889	14.64	439.74	47.00	0.79
Greenway	17400	6157	1383.06	1394.29		1397.78	0.003166	15.07	426.62	46.98	0.82
Greenway	17300.*	6157	1382.75	1394.00		1397.45	0.003105	14.98	429.58	46.99	0.82
Greenway	17200	6225	1382.43	1393.32		1397.09	0.003531	15.65	414.60	46.97	0.87
Greenway	17100.*	6225	1382.11	1392.98		1396.74	0.003511	15.63	415.66	46.97	0.87

Wood, Patel and Associates

Greenway Parkway Channel
CLOMR Flow Rates with the Improved Channel (Recommended Option 3.9)

Reach	River Sta	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
		(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
Greenway	17000	6225	1381.80	1392.62		1396.39	0.003526	15.66	415.38	46.98	0.87
Greenway	16900	6225	1381.48	1391.87	1391.53	1395.98	0.004037	16.33	396.99	46.96	0.92
Greenway	16800.*	6225	1381.16	1391.51		1395.57	0.003954	16.25	400.28	46.97	0.92
Greenway	16700.*	6225	1380.85	1391.15		1395.18	0.003886	16.18	403.16	46.99	0.91
Greenway	16600	6225	1380.53	1390.81		1394.78	0.003786	16.07	407.22	47.00	0.90
Greenway	16500.*	6225	1380.21	1390.49		1394.39	0.003680	15.95	411.68	47.02	0.89
Greenway	16400	6225	1379.89	1390.17		1394.01	0.003575	15.83	416.28	47.04	0.88
Greenway	16300.*	6225	1379.57	1389.83		1393.65	0.003548	15.80	417.67	47.04	0.88
Greenway	16200.*	6225	1379.26	1389.40		1393.29	0.003649	15.94	414.17	47.05	0.89
Greenway	16100	6225	1378.94	1388.85		1392.90	0.003898	16.28	405.60	47.04	0.92
Greenway	16000.*	6225	1378.63	1388.63		1392.46	0.003548	15.87	420.31	47.09	0.89
Greenway	15900	6225	1378.31	1388.43		1392.06	0.003241	15.47	437.90	51.05	0.86
Greenway	15800	6225	1377.99	1386.99	1386.99	1391.59	0.004575	17.39	387.00	47.10	1.02

Greenway Parkway Channel
Channel Improvements for Recommended Option 3.9

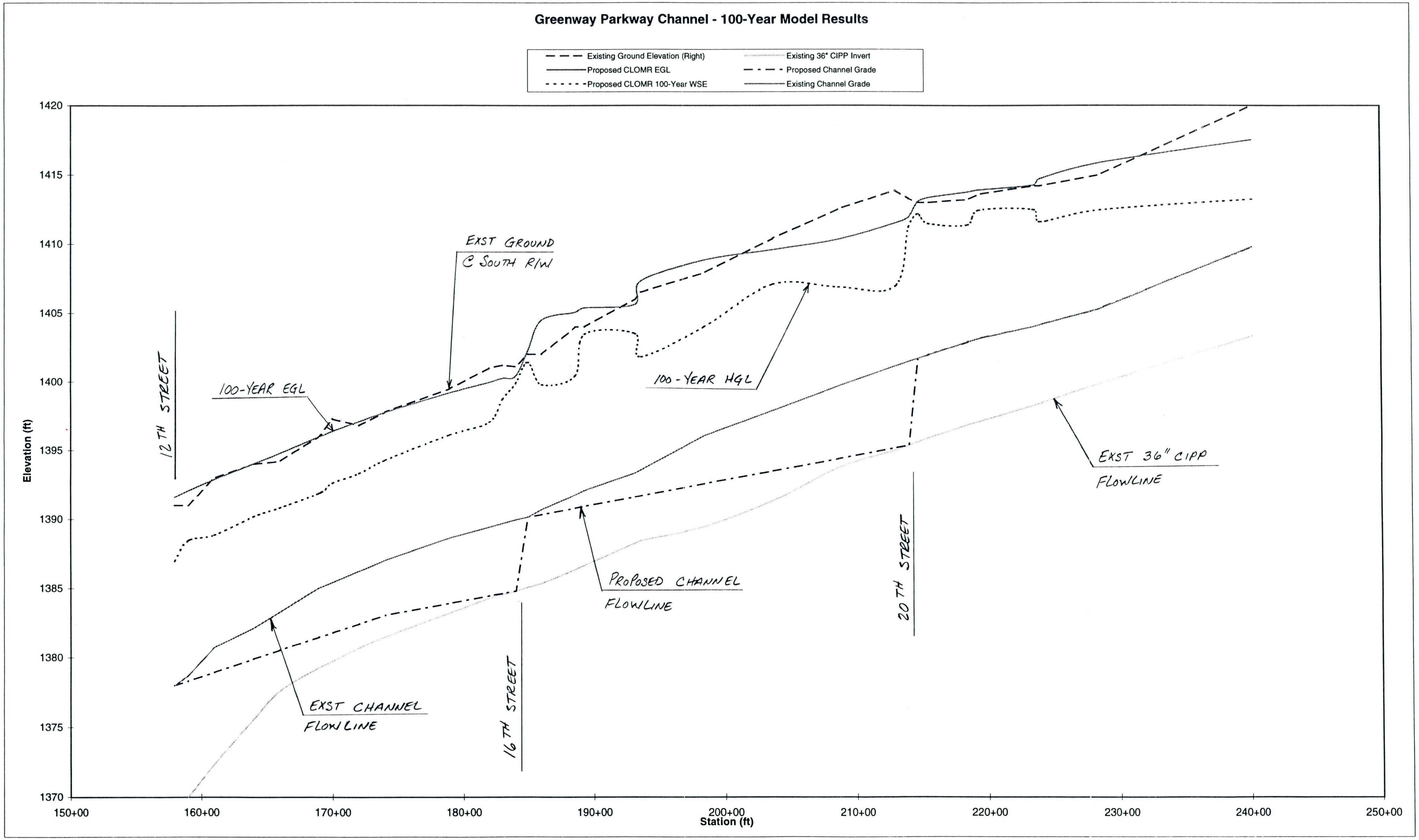


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Exhibit 7

Minutes from the Meeting with City Staff on October 6, 1997

<u>MINUTES OF MEETING</u>

October 6, 1997
WP # 96559

PROJECT: Greenway Parkway Channel

SUBJECT: Discussion of Alternatives and Preliminary Findings
CoP # Index ST-896829

DATE: October 6, 1997

ATTENDEES: Ralph Goodall, City of Phoenix
John Bethell, City of Phoenix
Ash Patel, Wood/ Patel
Fred Schneider, Wood/ Patel FS

Wood/Patel presented a brief overview of the project status and preliminary findings.

Wood/Patel described their concept of deepening the channel and reviewed the typical section presented to the City staff. The section consisted of either a 1:1, 1.5:1 and/or vertical wall from the existing channel invert to the proposed channel invert. It is anticipated that a 1:1 or 1.5:1 slope can be maintained throughout most of the project reach. In some locations, the channel may be deepened approximately six feet. Ralph was concerned about the vertical wall being a safety concern. It was agreed that the tallest vertical wall used will be three feet. The City stated that if a vertical wall is required, it should be placed along the north bank to limit the visibility of the wall from Greenway Parkway. Also, if widening the channel is required, it should be done to the north so that the existing twelve foot access bench area on the south bank is maintained. He indicated that by maintaining a maximum wall height of three feet, an additional fence may not be required.

Wood/Patel presented the alternative of using the existing concrete box culvert structures (RCBC) at 16th and 20th Streets. The existing 36" CIPP storm drain under the channel and RCBC's would be utilized to convey low flows in the channel. However, during larger events where the storm flows exceed the capacity of the 36" pipe, flows would be conveyed through the RCBC. The City requested that maintenance access to the channel bottom be maintained similar to the existing condition, particularly at the box culvert locations. Therefore, ramps would be required from the channel bottom at all RCBC's and drop structures.

Wood/Patel presented the Dibble & Associates drawings for the 7th Street RCBC and the corresponding hydraulic grade line (HGL). Wood/Patel stated that based upon the drawing and HGL shown, during larger storm events a hydraulic jump may occur inside or upstream of the 7th Street structure causing a backwater effect. Also, Wood/Patel was unsure of what may happen at the 12th Street channel transition where the channel transitions from a lined channel to a natural channel. At this location, due to high outlet velocities from the lined channel section, an energy dissipating structure may be needed. A backwater effect may also take place at this location. This may become a critical issue when the CLOMR is requested of FEMA by the City of Phoenix. Therefore, Wood/Patel requested that their study section be extended to the 7th Street structure to verify that the proposed solution does not cause any adverse conditions. John will obtain the cross-section information, including HEC-2, from Dibble & Associates for Wood/Patel's use. Wood/Patel will prepare a fee estimate for extending the study reach once the information has been received.

Wood/Patel explained that the deepened channel sections will not have a low flow pipe. It was agreed that this was acceptable. However, the channel will have a low flow "v" section in the bottom to contain these flows.

Wood/Patel presented their preliminary cost estimate for the proposed channel section. A section of channel will need to be widened from 12th Street east by 1400 feet. Other than this section of widening, the channel would be deepened only. The preliminary cost estimate was $500,000 less than Dibble's estimate. However, it was discussed that Dibble's estimate involved removing and replacing the RCBC's, widening the channel on one side, replacing the 36" pipe under the channel, and using a 6" concrete lining. Whereas, Wood/Patel's proposed solution involved less channel reconstruction and a 7" concrete channel lining. Based upon the preliminary analysis, it is believed that a 7" lining will be required due to the estimated channel velocities. The increased channel lining thickness may increase Dibble's cost estimate by up to $500,000. Also, Dibble did not include a contingency for engineering or construction management costs. To maintain a cost comparison between Wood/Patel and Dibble's Analysis, Wood/Patel will develop two cost estimates. One cost estimate will be based on Wood/Patel's analysis and the other will be based on Dibble's analysis. This will allow an "Apples to Apples" cost comparison, as well as develop costs based on current construction costs.

Wood/Patel discussed the transitions and/or connections of the large diameter storm drains with the channel. During the design phase of the channel improvements, special attention should be paid to how these flows converge so that adverse conditions can be avoided.

Wood/Patel also discussed other options which were investigated and later eliminated based on costs, constructability, public perception, and overall project impacts. Options investigated included the following:

1) Construction of a detention basin at Greenway and Cave Creek Roads. The basin will contain all flows entering the channel at the upstream end. The estimated cost including land, excavation, landscaping, and miscellaneous was $4,800,000. This option was rejected since the reduced flows were still not contained within the existing channel banks.

2) Another option was deepening the existing detention basins and reducing downstream flows. The estimated costs were approximately $2,000,000 for each basin. However, pump stations and re-landscaping would be required. This option was rejected since the resulting reduced flows were still not contained within the existing channel banks.

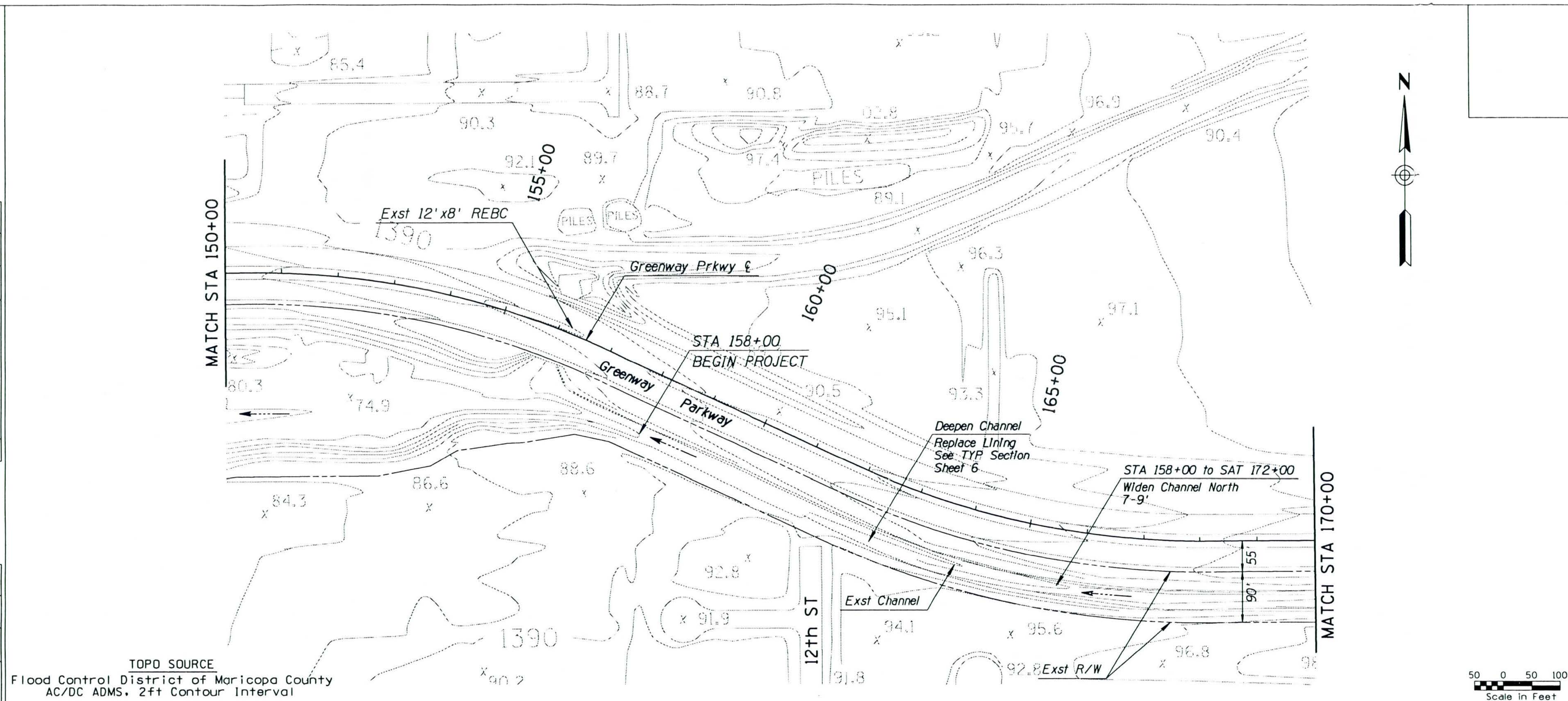
Other options evaluated include use of undeveloped land for detention basins near 16th street and Greenway Parkway, Bell Road and 20th Street, and developed land for detention basins near 20th Street and Greenway Parkway and Cave Creek and Bell Roads. These options were not evaluated further due to the excessive land acquisition and construction costs as well as the small positive impacts on overall stormwater flow reduction.

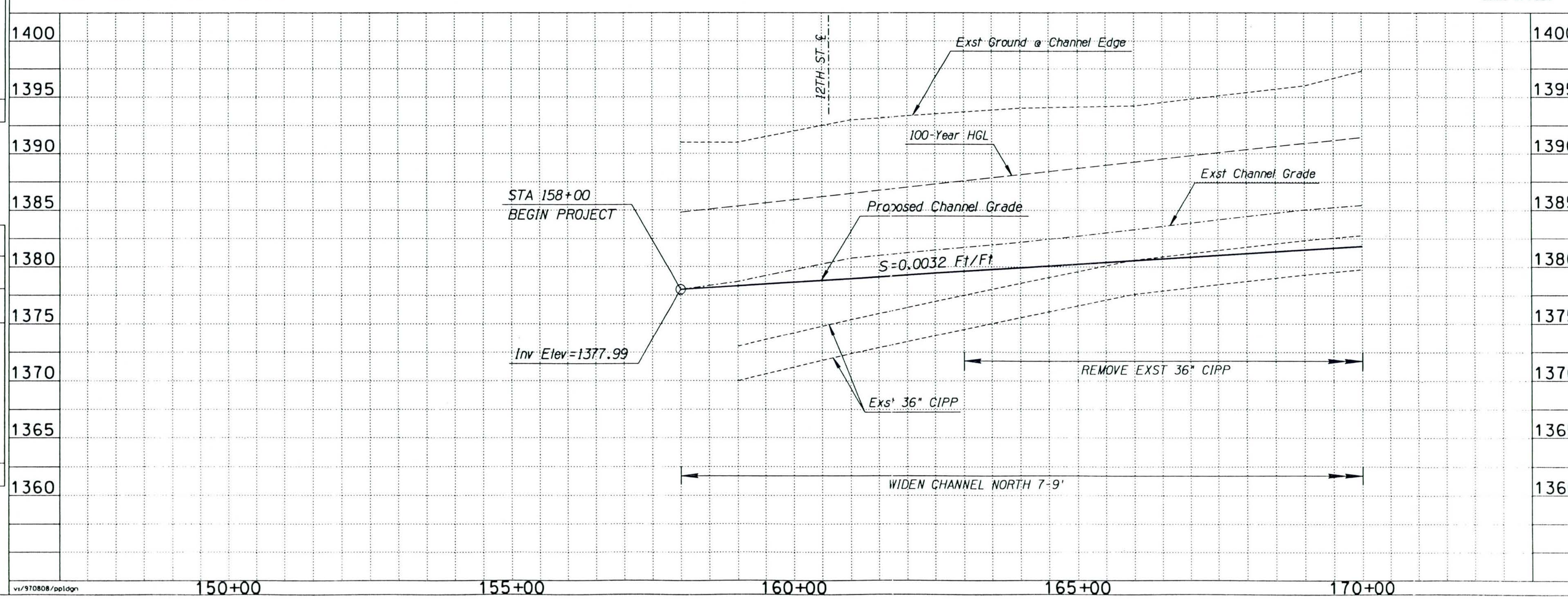
cc: Attendees
Mr. Ray Acuna, Floodplain Manager, City of Phoenix

Memos\96559.o08

Exhibit 8

Preliminary Plan and Profile for Selected Improvement Option





F.H.W.A. REGION	STATE	PROJ. NO.	NO.	TOTAL	AS BUILT
9	ARIZ				

CONSULTING ENGINEER

DES FKS | DR: SR | CK: ACP | DATE:10/97

REVISION BY CITY OF PHOENIX

NO.	DESCRIPTION	REV BY	CKD BY	DATE

CONCEPT PLANS, NOT FOR CONSTRUCTION OR RECORDING

WOOD, PATEL & ASSOCIATES, INC.
1550 EAST MISSOURI, SUITE 203
PHOENIX, ARIZONA (602) 234-1344

CITY OF PHOENIX, ARIZONA
STREET TRANSPORTATION DEPARTMENT

GREENWAY PARKWAY CHANNEL
12TH STREET TO CAVE CREEK ROAD
ST-955468

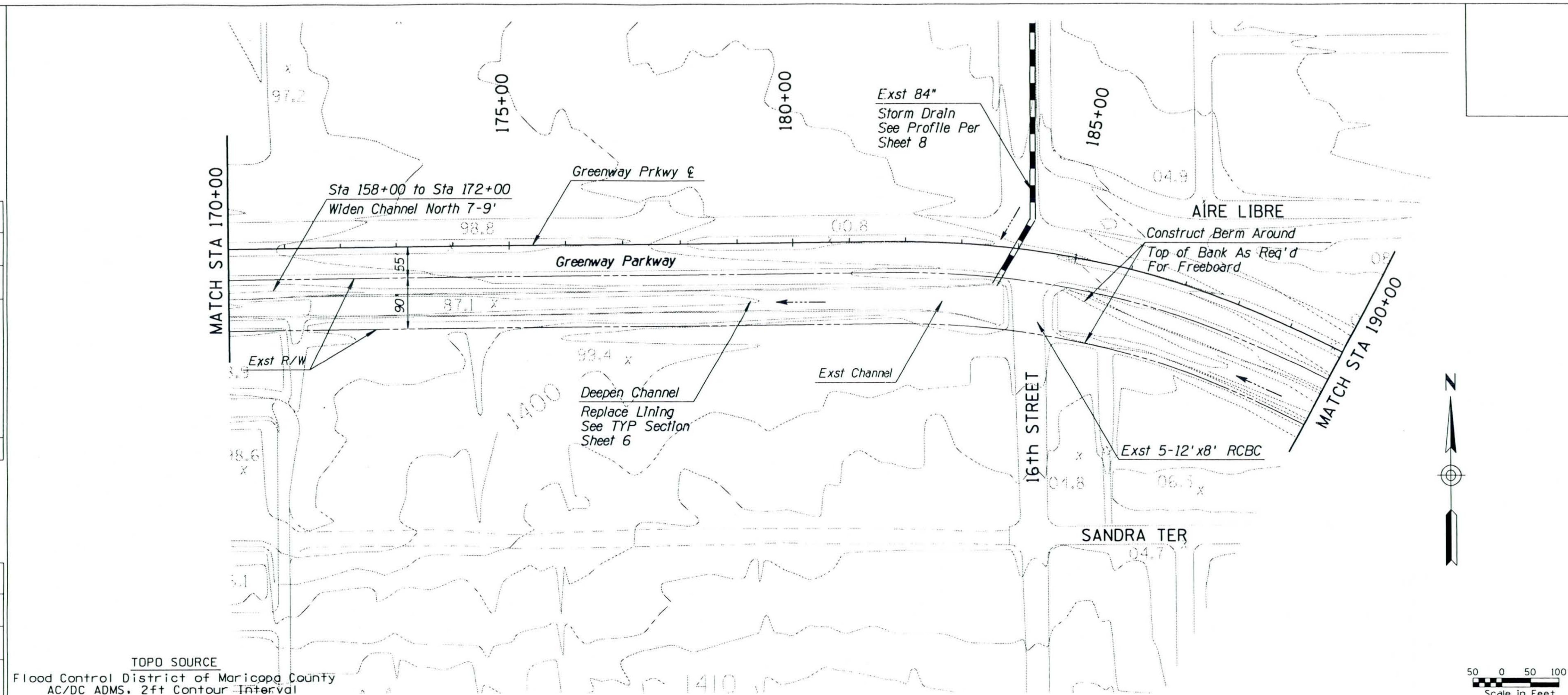
DR SR DATE:	DES FKS DATE:	CK ACP DATE:	SHEET NO.	TOTAL SHEETS	AS BUILT
SCALE:	HORIZONTAL VERTICAL		1		

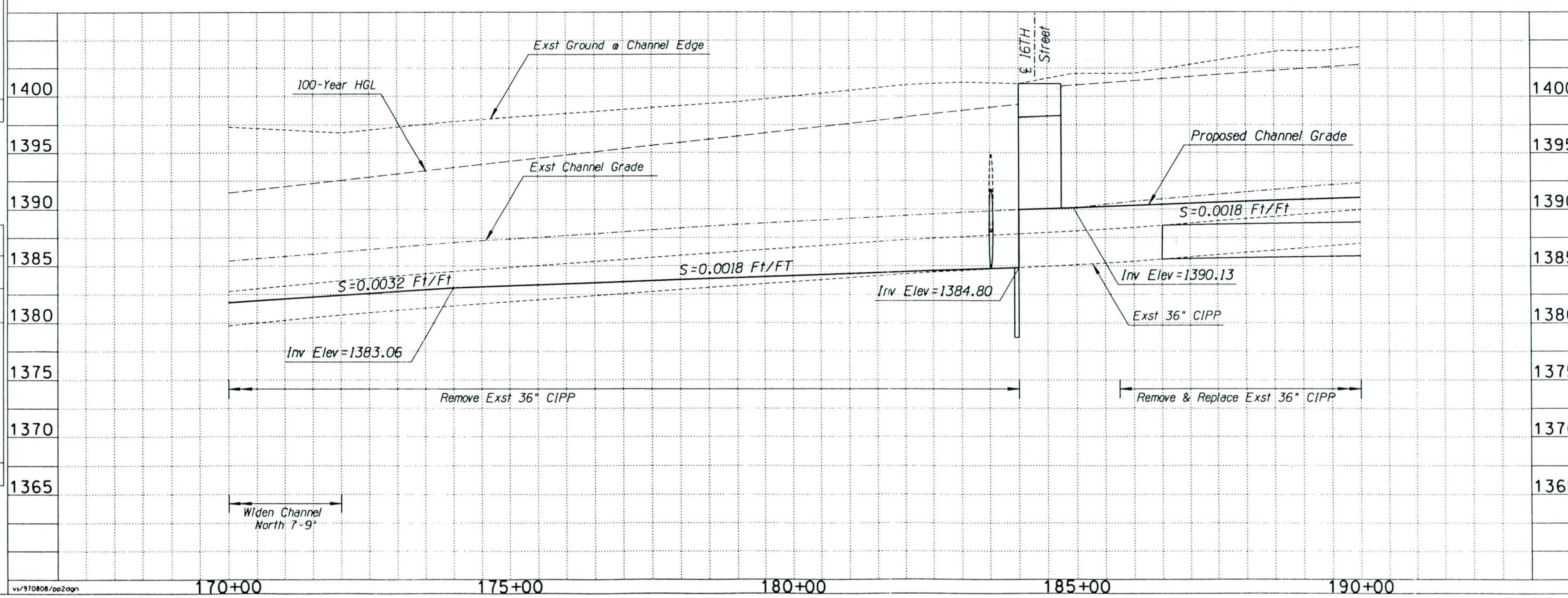
vr/970808/ppldgn

F.H.W.A. REGION	STATE	PROJ. NO.	NO.	TOTAL	AS BUILT
9	ARIZ				

CONSULTING ENGINEER

DES FKS | DR: SR | CK: ACP | DATE:10/97





REVISION BY CITY OF PHOENIX

NO.	DESCRIPTION	REV BY	CKD BY	DATE

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REVISION BY CITY OF PHOENIX

NO.	DESCRIPTION	REV BY	CKD BY	DATE

CONCEPT PLANS, NOT FOR CONSTRUCTION OR RECORDING

WOOD, PATEL & ASSOCIATES, INC.
1550 EAST MISSOURI, SUITE 203
PHOENIX, ARIZONA (602) 234-1344

CITY OF PHOENIX, ARIZONA
STREET TRANSPORTATION DEPARTMENT

GREENWAY PARKWAY CHANNEL
12TH STREET TO CAVE CREEK ROAD
ST-955468

DR SR DATE:	DES FKS DATE:	CK ACP DATE:	SHEET NO.	TOTAL SHEETS	AS BUILT
SCALE:	HORIZONTAL VERTICAL		2		

F.H.W.A. REGION	STATE	PROJ. NO.	NO.	TOTAL	AS BUILT
9	ARIZ				

CONSULTING ENGINEER

DES FKS	DR: SR	CK: ACP	DATE:10/97

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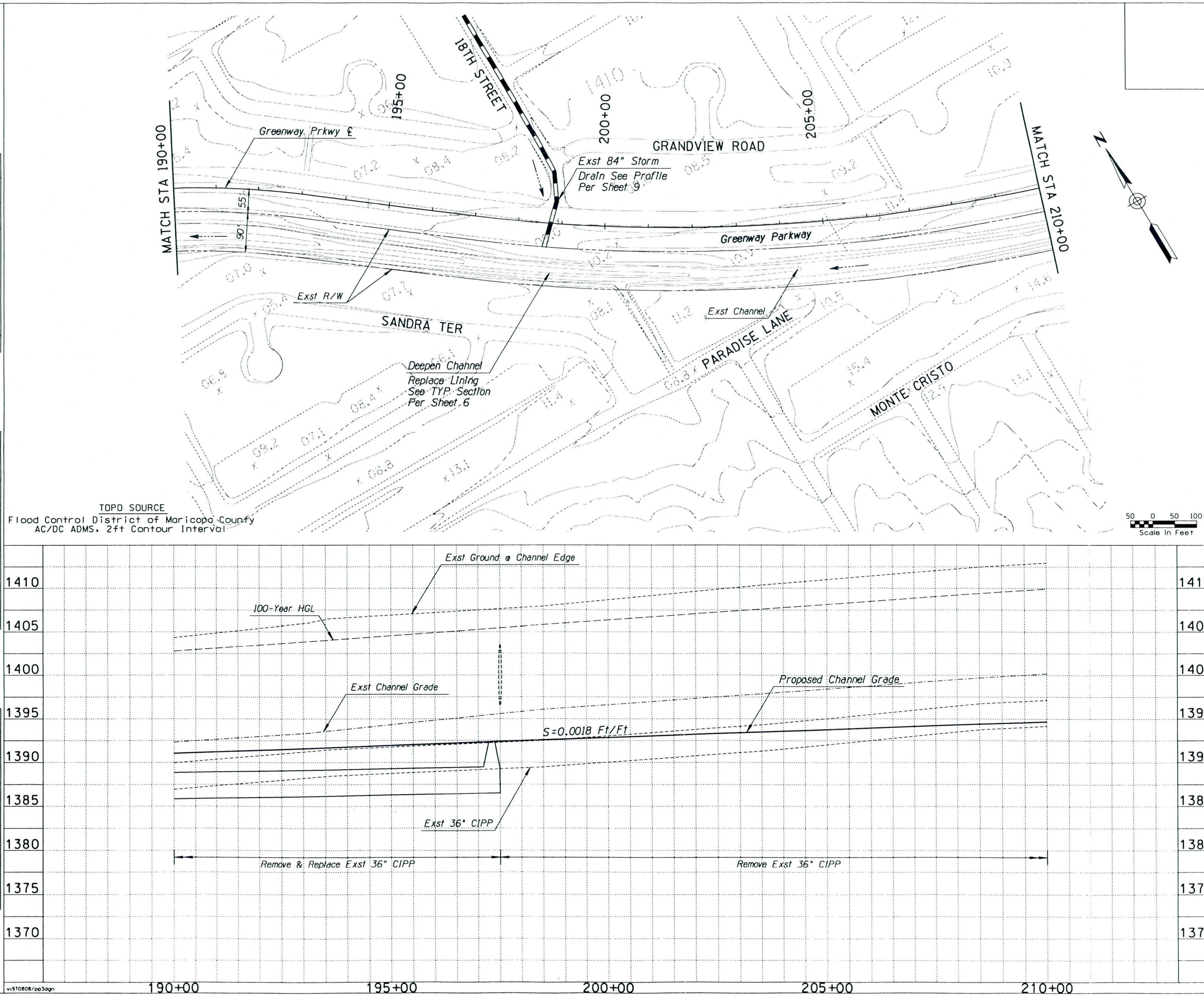
NO.	REVISION BY CITY OF PHOENIX DESCRIPTION	REV BY	CKD BY	DATE



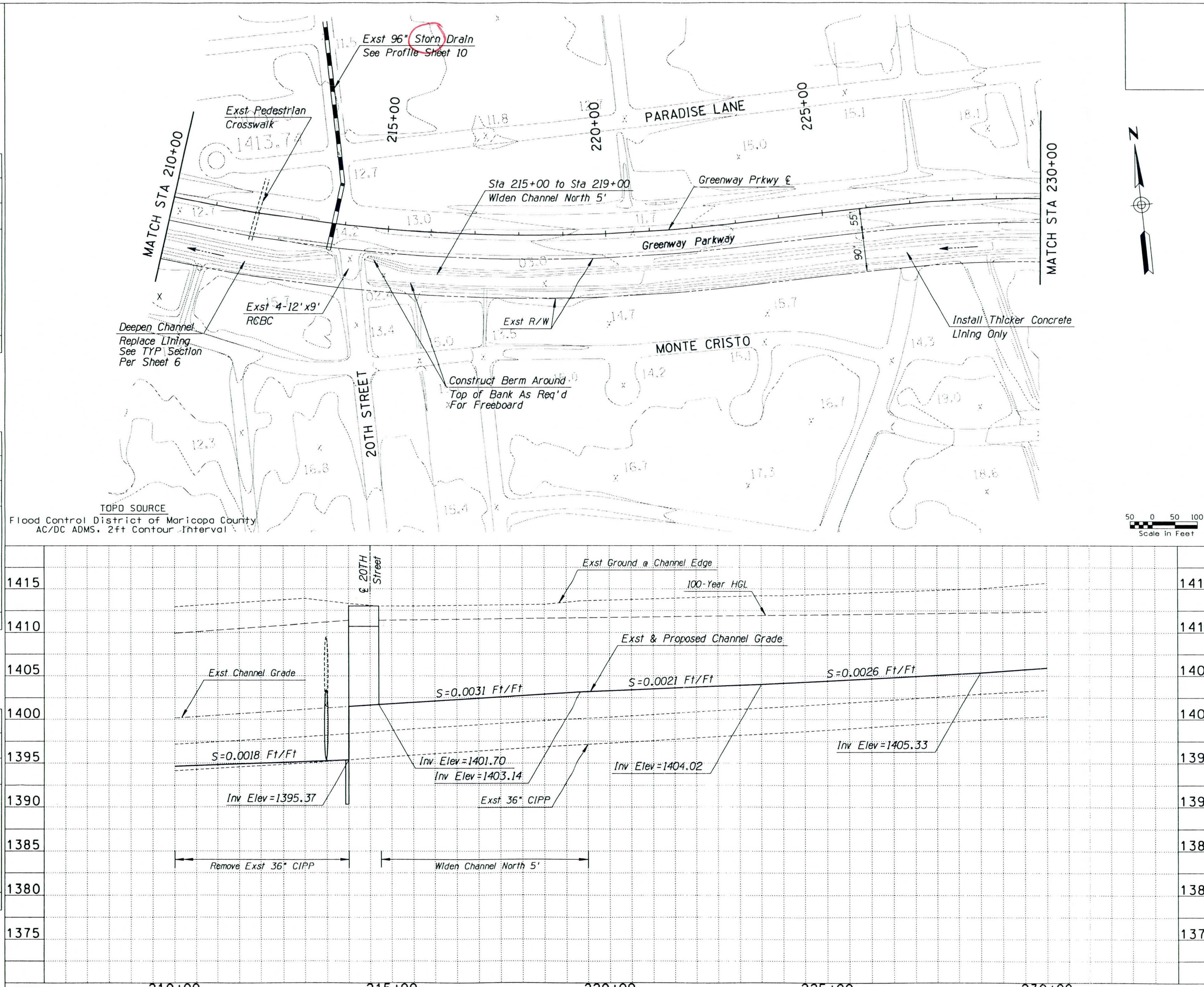
CONCEPT PLANS, NOT FOR CONSTRUCTION OR RECORDING

WOOD, PATEL & ASSOCIATES, INC.
1550 EAST MISSOURI, SUITE 203
PHOENIX, ARIZONA (602) 234-1344

CITY OF PHOENIX, ARIZONA
STREET TRANSPORTATION DEPARTMENT

GREENWAY PARKWAY CHANNEL
12TH STREET TO CAVE CREEK ROAD
ST-955468

DR SR DATE:	DES FKS DATE:	CK ACP DATE:	SHEET NO.	TOTAL SHEETS	AS BUILT
SCALE:	HORIZONTAL VERTICAL		3		



REVISION BY CITY OF PHOENIX				
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F.H.W.A. REGION	STATE	PROJ. NO.	NO.	TOTAL	AS BUILT
9	ARIZ				

CONSULTING ENGINEER

DES FKS | DR: SR | CK: ACP | DATE:10/97

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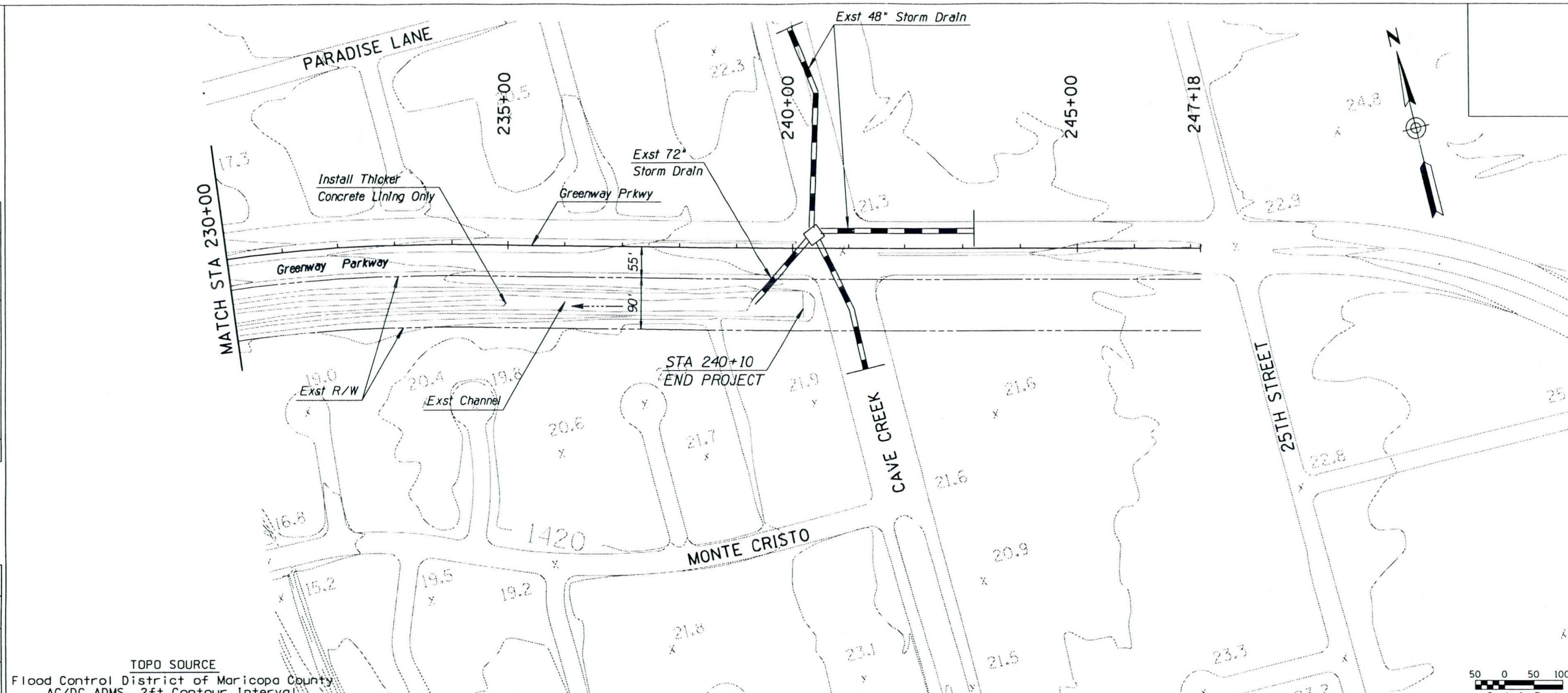
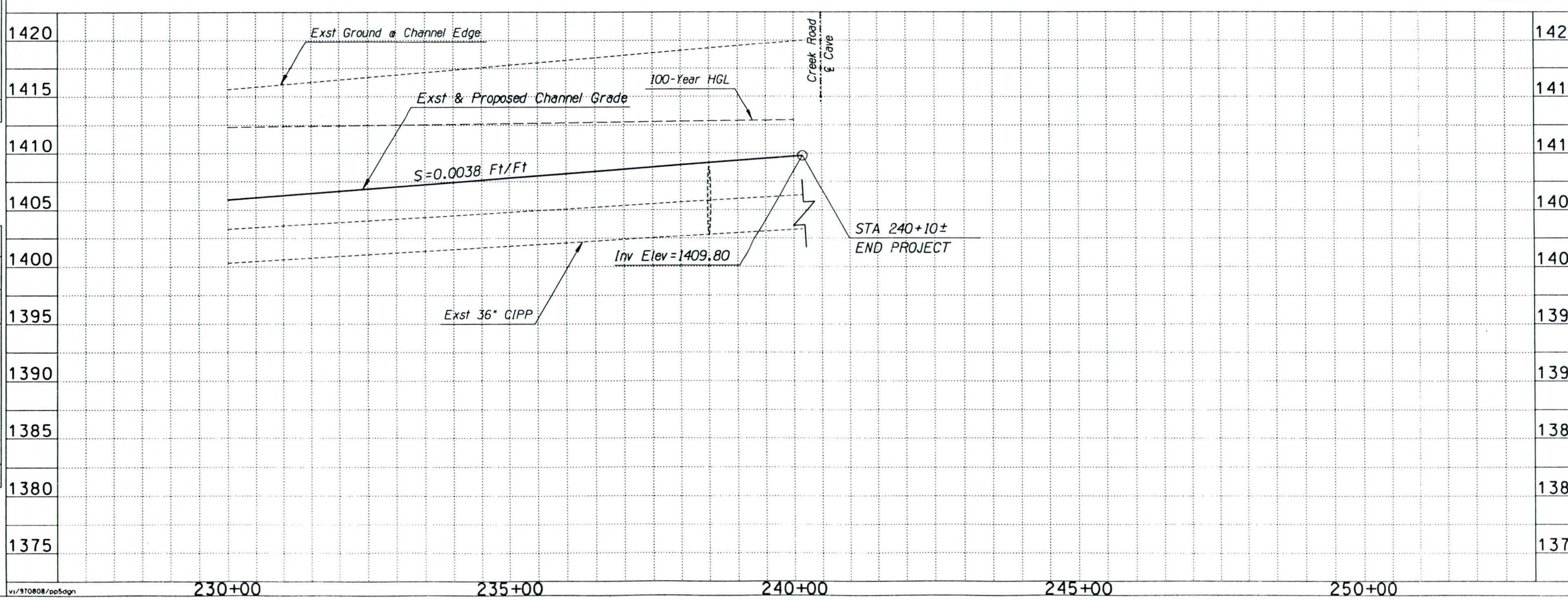
CITY OF PHOENIX, ARIZONA
STREET TRANSPORTATION DEPARTMENT

GREENWAY PARKWAY CHANNEL
12TH STREET TO CAVE CREEK ROAD
ST-955468

DR SR DATE:	DES FKS DATE:	CK ACP DATE:	SHEET NO.	TOTAL SHEETS	AS BUILT
SCALE:	HORIZONTAL VERTICAL		4		

vi/970808/pp4dgn





F.H.W.A. REGION	STATE	PROJ. NO.	NO.	TOTAL	AS BUILT
9	ARIZ				

CONSULTING ENGINEER

DES FKS | DR: SR | CK: ACP | DATE:10/97

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CITY OF PHOENIX, ARIZONA
STREET TRANSPORTATION DEPARTMENT

GREENWAY PARKWAY CHANNEL
12TH STREET TO CAVE CREEK ROAD
ST-955468

DR SR DATE:	DES FKS DATE:	CK ACP DATE:	SHEET NO.	TOTAL SHEETS	AS BUILT
SCALE:		HORIZONTAL VERTICAL	5		

vi/970808/pp5dgn

NO.	DESCRIPTION	REV BY	CKD BY	DATE

REVISION BY CITY OF PHOENIX

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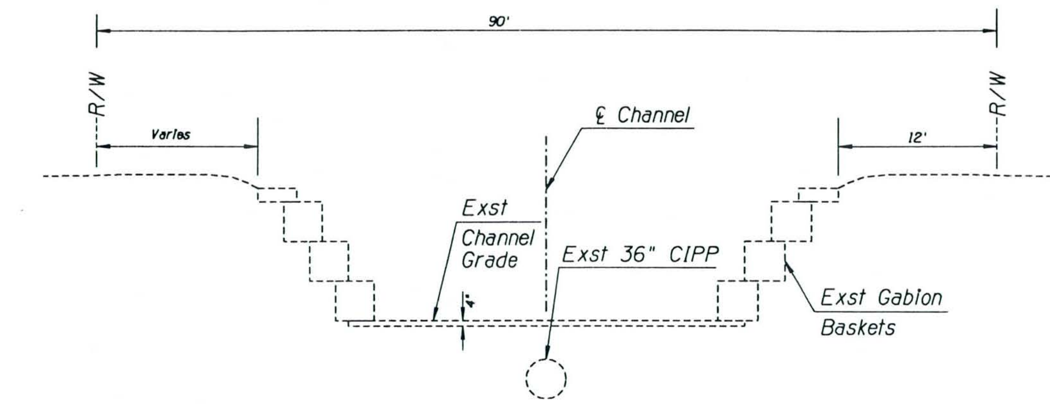
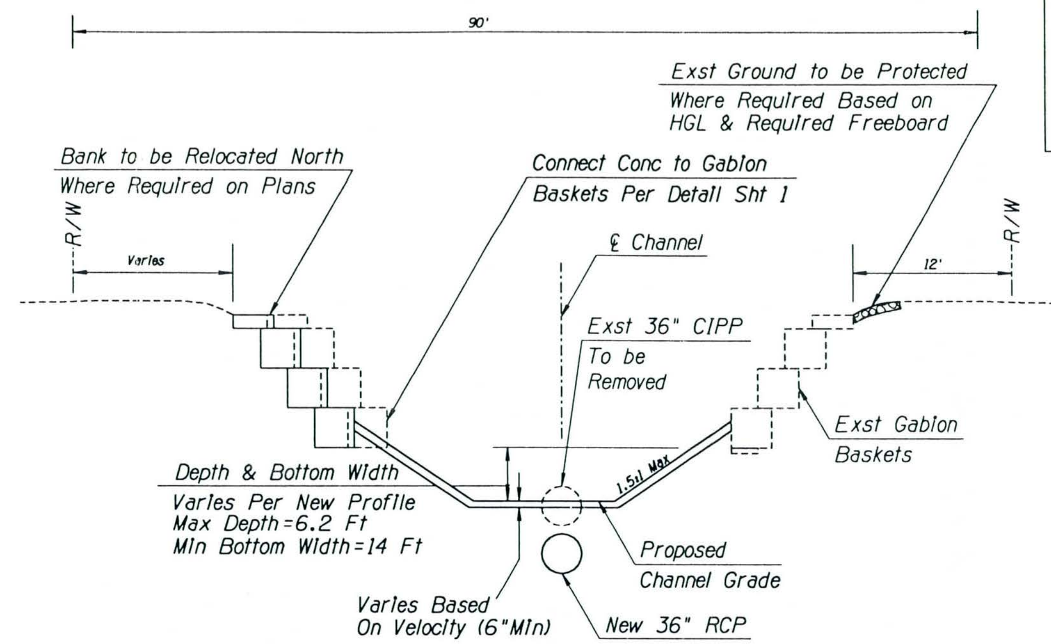
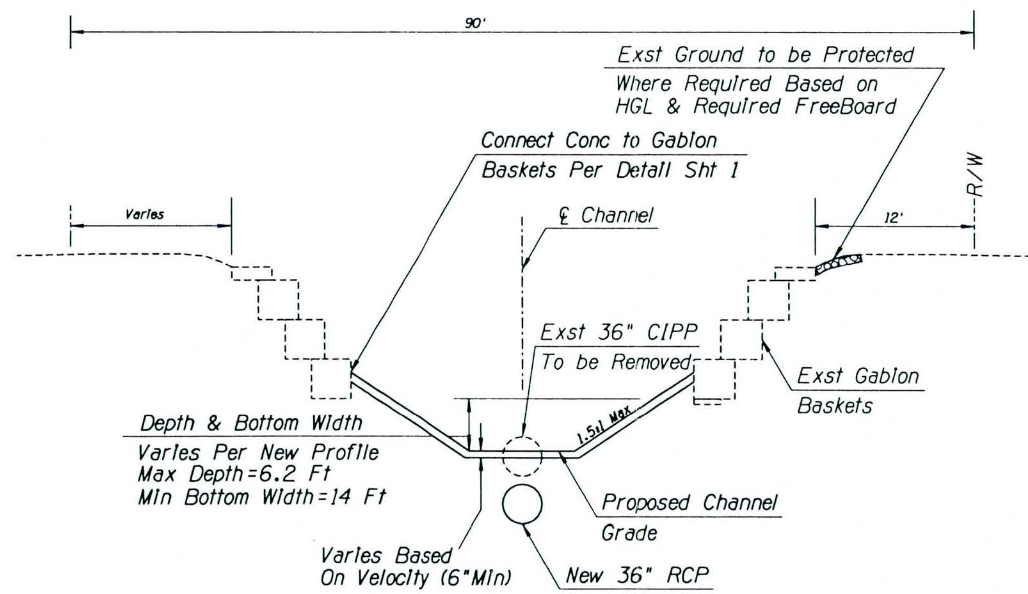
REVISION BY CITY OF PHOENIX



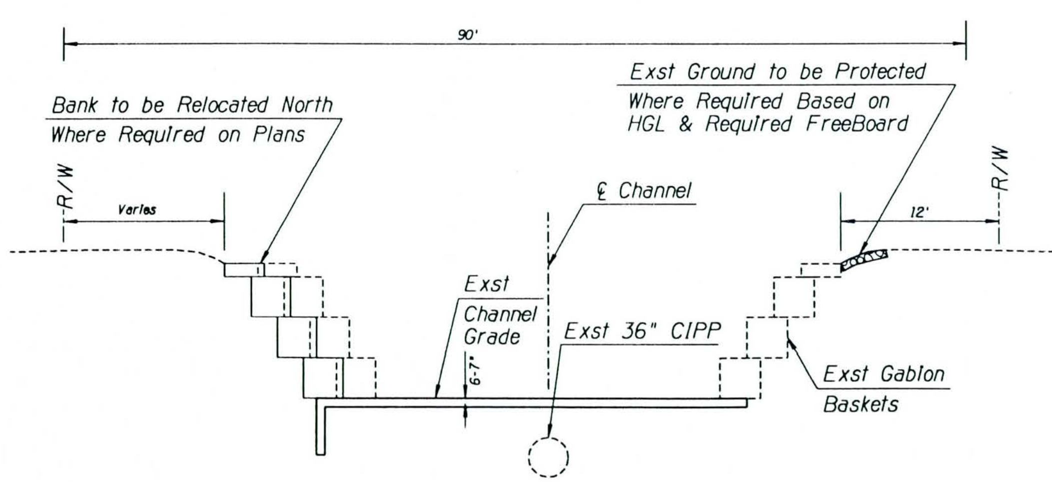
Typical Channel Section-Existing Condition



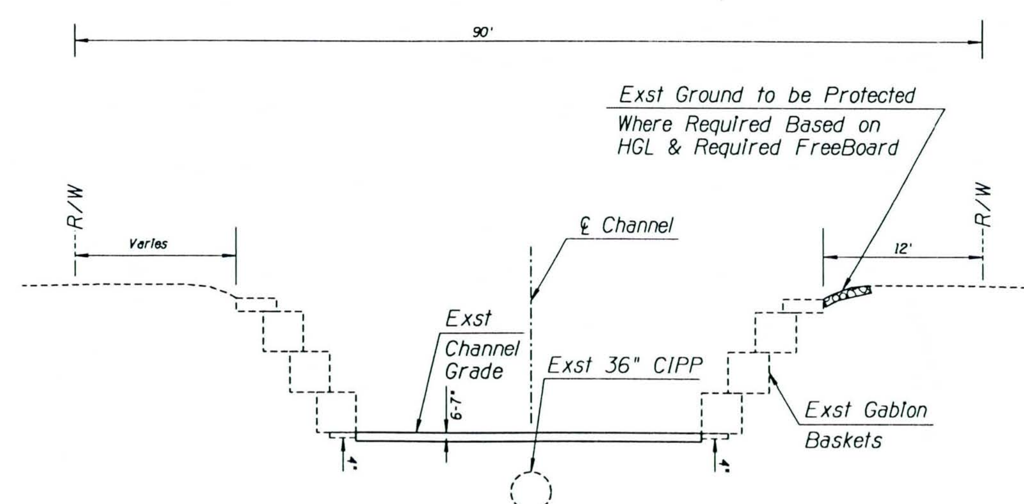
Typical Section Sta 158+00 to 172+00



Typical Section Sta 172+00 to 214+70



Typical Section Sta 214+70 to 219+70



Typical Section Sta 219+70 to 240+10±

F.H.W.A. REGION	STATE	PROJ. NO.	NO.	TOTAL	AS BUILT
9	ARIZ				

CONSULTING ENGINEER

DES FKS	DR: SH	CK: ACP	DATE: 10/97

NOTE:
ALL SECTIONS LOOKING UPSTREAM

CONCEPT PLANS, NOT FOR CONSTRUCTION OR RECORDING

WOOD, PATEL & ASSOCIATES, INC.
1550 EAST MISSOURI, SUITE 203
PHOENIX, ARIZONA (602) 234-1344

CITY OF PHOENIX, ARIZONA
STREET TRANSPORTATION DEPARTMENT

GREENWAY PARKWAY CHANNEL
12TH STREET TO CAVE CREEK ROAD
ST-955468

DR. SH DATE:	DES. FKS DATE:	CK. ACP DATE:	SHEET NO.	TOTAL SHEETS	AS BUILT
SCALE:	HORIZONTAL VERTICAL		6		

F.H.W.A. REGION	STATE	PROJ. NO.	NO.	TOTAL	AS BUILT
9	ARIZ				

CONSULTING ENGINEER

DES JAC | DR: SR | CK: FKS | DATE: 11/97

REVISION BY CITY OF PHOENIX

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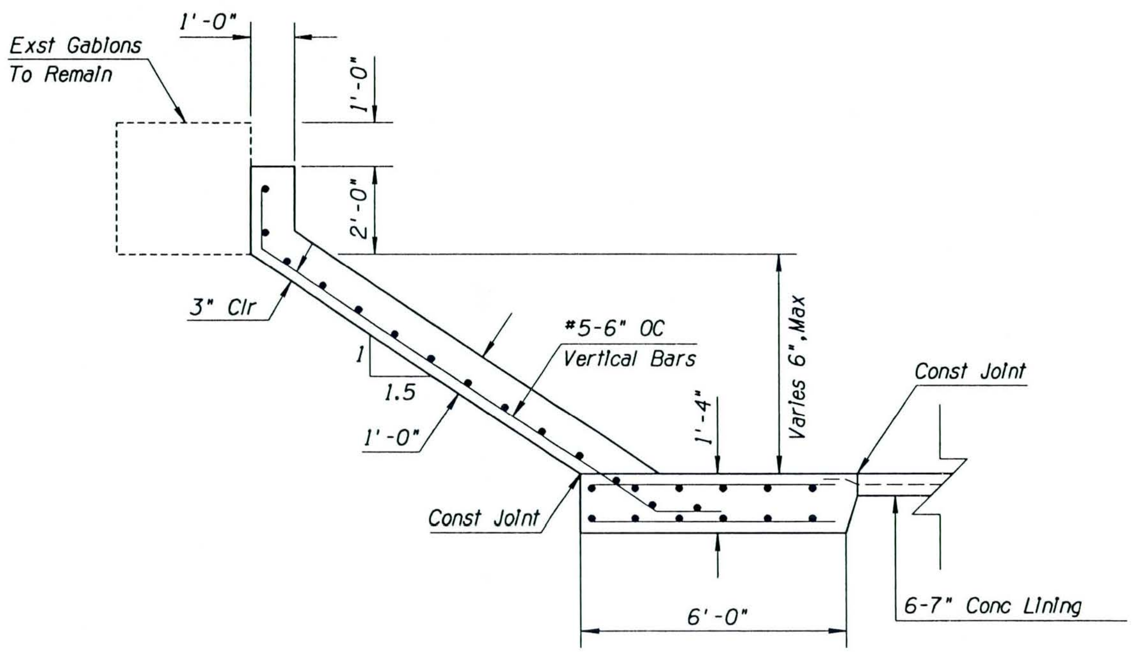
NO.	DESCRIPTION	REV BY	CKD BY	DATE

REVISION BY CITY OF PHOENIX

NO.	DESCRIPTION	REV BY	CKD BY	DATE

Notes:

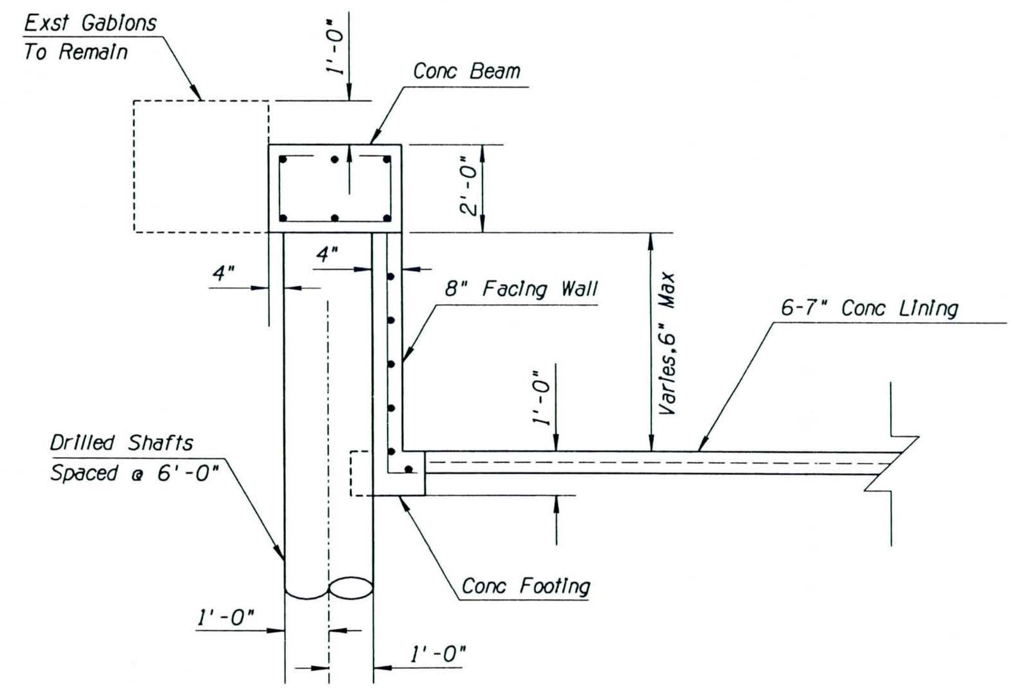
1. Need To Verify Soil Conditions at Site
2. May Require Building Short Sections of New Wall or Temp Shoring Gabions
3. Conc =3000 PSI @ 28 Days



SECTION - ALT 1 CANTILEVER RETAINING WALL

Notes:

1. Need To Verify Soil Conditions at Site
2. Drilled Shaft Resist Temp Loads During Construction



SECTION - ALT 2 DRILLED SHAFTS

CONCEPT PLANS, NOT FOR CONSTRUCTION OR RECORDING

CANON & ASSOCIATES, INC.
3410 E. UNIVERSITY DRIVE, SUITE 390
PHOENIX, AZ 85034 (602) 470-8477

CITY OF PHOENIX, ARIZONA
STREET TRANSPORTATION DEPARTMENT

GREENWAY PARKWAY CHANNEL
12TH STREET TO CAVE CREEK ROAD
ST-955468

DR. SR DATE:	DES. JAC DATE:	CK. FKS DATE:	SHEET NO.	TOTAL SHEETS	AS BUILT
SCALE:	HORIZONTAL VERTICAL		7		

REVISION BY CITY OF PHOENIX				
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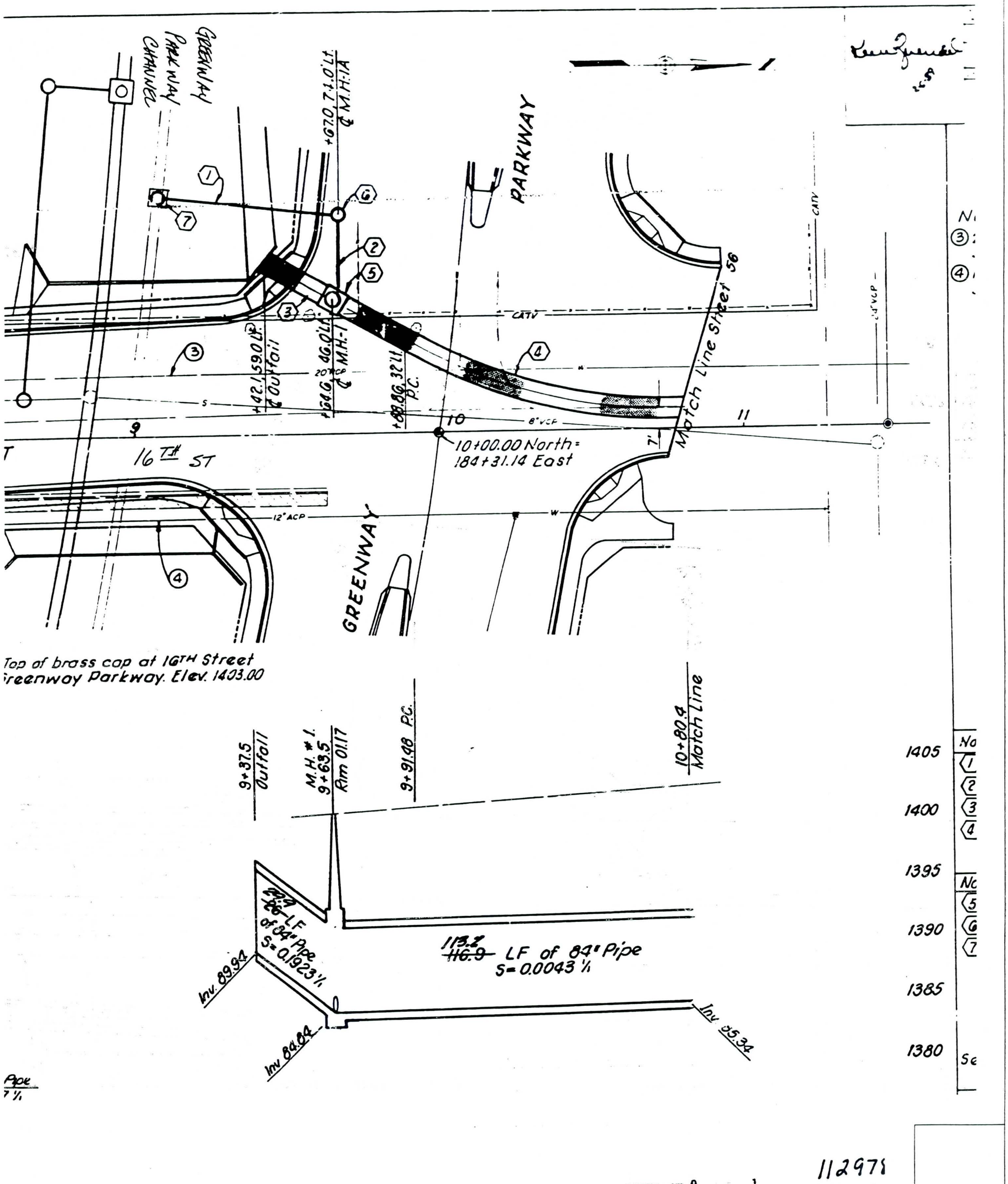


CONCEPT PLANS. NOT FOR CONSTRUCTION OR RECORDING

WOOD, PATEL & ASSOCIATES, INC.
1550 EAST MISSOURI, SUITE 203
PHOENIX, ARIZONA (602) 234-1344

CITY OF PHOENIX, ARIZONA
STREET TRANSPORTATION DEPARTMENT

GREENWAY PARKWAY CHANNEL
12TH STREET TO CAVE CREEK ROAD
ST-95468

DR: SR | DES: FKS | CK: ACP

SCALE: HORIZONTAL VERTICAL

SHEET NO. 8 | TOTAL SHEETS | AS BUILT

16TH ST - 84" STORM DRAIN
PLAN & PROFILE PER CITY OF PHOENIX
PROJECT NO. P-861013
BY: HOOK ENGINEERING
SHEET 55 OF 135

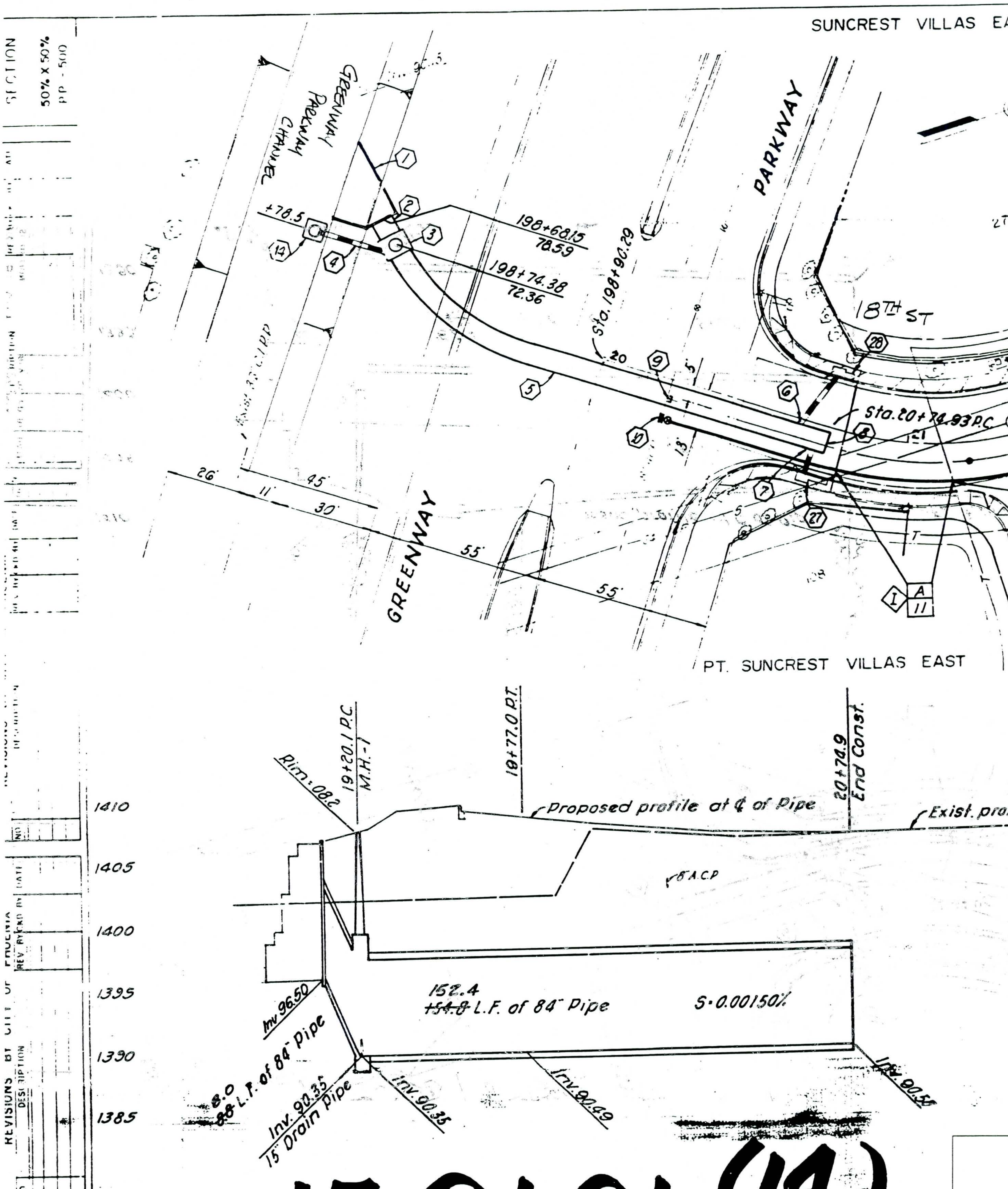
DES FKS | DR: SR | CK: ACP | CONSULTING ENGINEER DATE: 10/97

F.H.W.A. REGION 9 | STATE ARIZ | PROJ. NO. | NO. | TOTAL | AS BUILT

REVISION BY CITY OF PHOENIX				
NO.	DESCRIPTION	REV BY	CKD BY	DATE

REVISION BY CITY OF PHOENIX				
NO.	DESCRIPTION	REV BY	CKD BY	DATE

REVISION BY CITY OF PHOENIX				
NO.	DESCRIPTION	REV BY	CKD BY	DATE



WOOD, PATEL & ASSOCIATES, INC.
1550 EAST MISSOURI, SUITE 203
PHOENIX, ARIZONA (602) 234-1344

CITY OF PHOENIX, ARIZONA
STREET TRANSPORTATION DEPARTMENT

GREENWAY PARKWAY CHANNEL
12TH STREET TO CAVE CREEK ROAD
ST-955468

DR: SR | DES: FKS | CK: ACP
DATE: | DATE: | DATE:
SCALE: HORIZONTAL / VERTICAL
SHEET NO. 9 | TOTAL SHEETS | AS BUILT

CONCEPT PLANS. NOT FOR CONSTRUCTION OR RECORDING

18TH ST - 84" STORM DRAIN
PLAN & PROFILE PER CITY OF PHOENIX
PROJECT NO. P-861013
BY: HOOK ENGINEERING
SHEET 60 OF 135

DES FKS | DR: SR | CK: ACP
CONSULTING ENGINEER DATE: 10/97

F.H.W.A. REGION	STATE	PROJ. NO.	NO.	TOTAL	AS BUILT
9	ARIZ				

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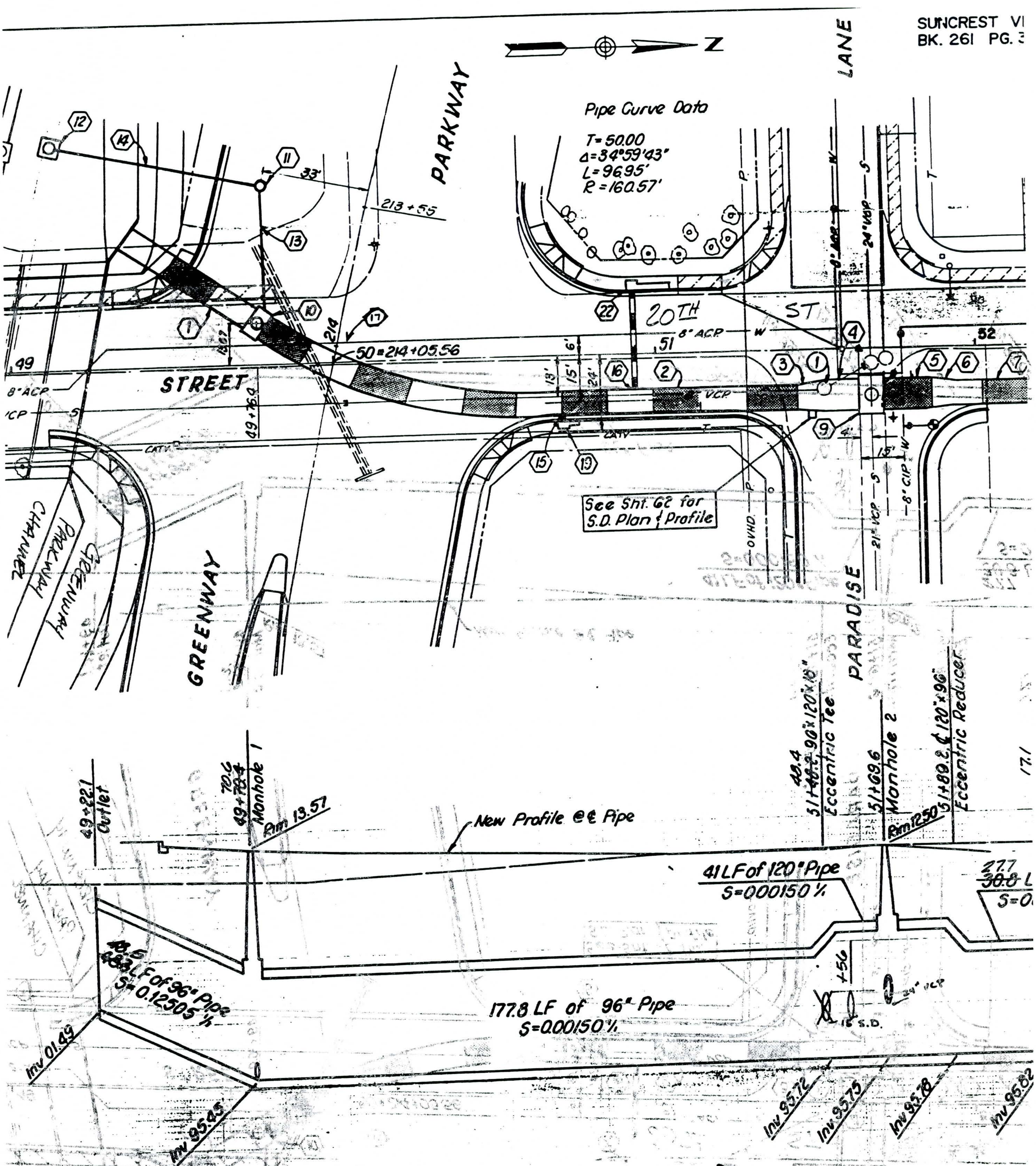
REVISION BY CITY OF PHOENIX				
NO.	DESCRIPTION	REV BY	CKD BY	DATE



15-91-21 (15)

20TH ST – 96" STORM DRAIN
PLAN & PROFILE PER CITY OF PHOENIX
PROJECT NO. P-861013
BY: HOOK ENGINEERING
SHEET 61 OF 135

CONCEPT PLANS. NOT FOR CONSTRUCTION OR RECORDING

WOOD, PATEL & ASSOCIATES, INC.
1550 EAST MISSOURI, SUITE 203
PHOENIX, ARIZONA (602) 234-1344

CITY OF PHOENIX, ARIZONA
STREET TRANSPORTATION DEPARTMENT

GREENWAY PARKWAY CHANNEL
12TH STREET TO CAVE CREEK ROAD
ST-95468

DES FKS | DR: SR | CK: ACP | CONSULTING ENGINEER DATE: 10/97

SHEET NO. 10