Cactus Road Storm Drain,

Alternate Conduit Section and Materials Comparison Report,

June 1992

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for

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CACTUS ROAD STORM DRAIN

ALTERNATE CONDUIT SECTION & MATERIAL COMPARISON REPORT

FOR

FLOOD CONTROL DISTRICT OF MARICOPA COUNTY

JUNE 1992

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CACTUS ROAD STORM DRAIN
ALTERNATIVE CONDUIT SECTION AND
MATERIAL EVALUATION REPORT

1. INTRODUCTION

The Cactus Road Storm Drain project consists of constructing a storm drain trunkline along Cactus Road from 67th Avenue to the Agua Fria Outer Loop Freeway (figure 1) capable of handling the 10-year storm event. As a portion of the design services to be performed, various conduit materials and sections have been evaluated to determine those that would be most suitable for this particular installation.

Final design flows, established using the Flood Control District of Maricopa County Hydrologic Design Manual, vary from 213 cfs at the upstream end (67th Avenue) to 1,000 cfs at the downstream end (Agua Fria Outer Loop). Corresponding pipe diameters, for a pipe flowing full but with nominal hydraulic pressure, will vary from 78 to 120 inch. Comparable box conduit sizes would vary from 7 ft x 5 ft to 10 ft x 9 ft.

Final alignment of the storm drain, both horizontally and vertically, is affected by the existing utilities in Cactus Road. However, a minimum 4-foot cover will be maintained with total trench depth for the 78- to 120-inch diameter pipe varying from about 11 to 20 ft. The variety of utilities located in and crossing Cactus Road include natural gas lines, sanitary sewer service lines, 18 and 30 inch sanitary sewer collection lines, water distribution and service lines, cable television lines, Salt River Project irrigation pipelines, telephone service lines, electric service lines, and a 7.2 kV electric line. All effort to avoid these utilities will be made. However, the mere existence of significant numbers of utilities has an impact on the selection of precast versus cast-in-place conduit materials.

Soil samples have been taken along the storm drain alignment and analyzed. A soils report has been prepared defining the types and nature of the soils along the storm drain alignment. Based on soils data, certain conduit materials may be deemed unsuitable. Section 4 presents the basic soils data and the potential impact on the conduit alternatives.

2. STORM DRAIN CONDUIT ALTERNATIVES

The basic design criteria for the storm drain include:

- 10-year return period storm.
- 75- to 100-year life of conduit material.
- Ability to carry flow rates varying from 213 to 1,000 cfs.
- Full flowing pipe at full capacity.
- Hydraulic grade line must be maintained below road elevation and elevation required to drain local catch basins.
- Minimize traffic interference.
- Reasonable construction time frame.

Based on this criteria, five conduit materials have been deemed suitable for evaluation as possible construction alternatives:

- Reinforced Concrete Pipe (RCP).
- Concrete-Lined Corrugated Metal Pipe (CLCMP).
- Precast Box.
- Cast-In-Place Pipe (CIPP).
- Cast-In-Place Box (CIP Box).

3. EVALUATION OF STORM DRAIN CONDUIT ALTERNATIVES

In this section, the five conduit material alternatives will be evaluated on the design criteria listed above.

3.1 Reinforced Concrete Pipe (RCP)

Of the five conduit materials RCP is by far the most common material for installations that require the shortest construction time with the greatest flexibility to be routed around utilities. This material has an excellent track record for durability and minimal long-term maintenance, particularly in these diameters. RCP manufacturers claim that for all practical purposes, their material will last forever; not technically true, but with proper construction and installation, the life of the pipe far exceeds a 75- to 100-year life. Good quality control during construction of the pipeline material itself can be maintained without strict field inspection because the pipe is constructed in a factory and not on-site. In addition, the pipe is a rigid structure and the backfill requirements can be much less stringent than for other conduit materials, further easing field inspection requirements. Other advantages include: (1) a wide variety of local manufacturers providing good availability with a fair amount of competition between manufacturer's prices; (2) relatively fast installation and therefore reduced traffic control problems; and (3) invert erosion in high-sediment conditions is seldom a problem.

The greatest disadvantage to RCP is associated with the rigid nature of the pipe and the resulting installation considerations. To achieve the rigid structure of RCP, large quantities of rebar and concrete are used that make the pipe heavy and hard to handle. To provide reasonable manageability, pipe segments are kept short. In these diameters (78 to 120 inches) the pipe lengths are kept between 6 and 12 ft depending on the equipment and weight capacity of the particular job and contractor. Even with the reduced pipe segment lengths, each piece of pipe is relatively heavy requiring the use of one or two large cranes for installation. The delivery costs are also increased due to the reduced number of pipe segments that can be delivered to the job site at one time. Table 1 further evaluates the weight considerations of RCP in relationship to other conduit materials. Section 5 fully evaluates the cost comparison of RCP to other conduit materials in terms of material cost (including delivery to the job site), installation cost and long-term Operation and Maintenance (O&M) cost.

3.2 Concrete-Lined Corrugated Metal Pipe (CLCMP)

3.2.1 Introduction to CLCMP. Corrugated Metal Pipe (CMP) is a conduit material that has been used extensively in short road crossing culvert situations that have not required an extremely long design life nor stringent hydraulic requirements. Relatively recent design changes or improvements have led to the use of CMP for longer storm drains and for locations that require a longer life. These improvements include use of aluminized coating and lining for corrosion protection and concrete lining for improved hydraulic performance in a given diameter.

Traditionally, CMP was constructed with no coating/lining, an asphalt coating/lining or a galvanized coating/lining. The life of the pipe is extended with coatings and linings, but neither asphalt nor galvanizing has allowed the CMP to be functional for more than 50 years in many installations. Aluminized coatings/linings appear to greatly extend metal life and reduce replacement requirements. G.E. Morris and L. Bednar prepared an evaluation of aluminized versus galvanized coatings for Armco, the predecessor to Contech Construction Products, Inc. (Contech) and the largest distributor of CLCMP in the area (appendix A1). The evaluation was based on 30-year field tests of drainage pipelines protected by aluminized and galvanized coatings, located and exposed together, in 54 sites and originally installed in 1952. The aluminized coating far out-performed the galvanized coating both on the interior and the exterior in all moisture conditions (extremely wet, moderate and dry climates) and in all soil conditions (moderately corrosive to severely corrosive). Aluminized coatings showed no attack or only minor localized coating loss with associated slight substrate penetration on the soil side. These studies helped provide guidelines for the suitability of aluminized coatings in various soil and drainage water conditions. Aluminized CMP is still not recommended for highly corrosive soils; resistivities below 1,500 ohm-cm and a pH range of 5 to 9. (It is already recognized that galvanized protection performs better than asphalt and aluminized coatings are also more durable than asphalt coatings. Aluminized coatings also perform better than asphalt coatings with the second improvement discussed below.)

The second improvement to CMP was the use of a concrete lining to improve hydraulic characteristics. The most modern method of applying the concrete lining is to apply the concrete from a revolving head moving inside the stationary metal pipe. Mechanical trowels immediately follow the spray head to provide a smooth finish. This equipment can also be used for applying linings in-situ. The concrete lining is added to a corrugated metal pipe (usually with aluminized coatings, but asphalt or galvanized can be used) with an inside diameter equivalent to the required diameter. The concrete lining is usually 3/8- to 3/4-inch thick at the crest of the interior corrugation and fills the corrugations.

CLCMP is designed as plain corrugated metal pipe with no allowance for structural contribution from the lining. The function of the lining is only to improve the hydraulic characteristics of the CMP and the lining is not intended to adhere to the metal pipe interior. Therefore, cracks or spalls in the lining do not create any structural integrity problems. The only concern is the hydraulic integrity if a large number of cracks or spalls are exhibited in the pipe (and a large number of these would be required to affect the hydraulic efficiency).

Hairline stress cracks are a common characteristic of CLCMP because the metal portion of the pipe is flexible and the concrete portion is rigid. As the concrete lining dries and as the pipe flexes during handling and installation, these cracks are formed. However, most are "healed" when the pipe is filled with water, according to the manufacturer and some studies.

CLCMP is a flexible rather than a rigid conduit. Rigid conduits, such as RCP, cannot deflect more than about 0.1 percent of their diameter without damage. Therefore, the rigid pipeline must be designed to carry the soil loads above and the arching soil load beside the pipe. Flexible conduits, however, may deflect as much as 5 percent under load without damage. In deflecting, these pipes transfer part of the vertical load into a horizontal thrust which is carried by the passive resistance of the soil beside the pipe. The reduction in forces leads to a reduction in steel requirements to offset the load. Aluminized coatings should not crack under the 5% deflection. Beyond that point, cracking and resultant corrosion are possible and likely.

In summary:

- Aluminized coatings and linings are superior to the more familiar galvanized or asphalt coatings and linings. Data is still limited to the 30-year installations studied by Armco and discussed above. That study provided guidelines for aluminized coated and lined CMP based on stormwater quality and soil resistivity. However, these guidelines provided for a 50-year life for 16-gauge CMP only. No guidelines were provided for 75- to 100-year life. Contech (the local supplier of CLCMP) estimates that if galvanized will last 50 to 55 years, then aluminized will last 80 to 100 years based on the comparison of performance between aluminized and galvanized coatings and linings in this 30-year study.

- Concrete lining of CMP improves the hydraulic characteristics to a comparable level with RCP. In addition, concrete lining further reduces or eliminates concern that the sediment load of stormwater will cause erosion of the pipe invert or that poor water quality will cause corrosion of the pipe interior.

- The number of local installations has increased in the Phoenix area over the last 10 years. Field inspection and data from pipelines ranging in size up to 96 inches is available. No significant deflection, spalling or failure of CLCMP has been reported. However, there are no local installations over 96 inches and few 120-inch diameter installations in the country. This project calls for 2 1/4 miles of pipe 108 inches and larger.

3.2.2 Evaluation of CLCMP. CLCMP has many advantages based on its flexible structure. Table 1 compares CLCMP with RCP in terms of weight and delivery lengths. CLCMP is significantly lighter than RCP and therefore can come in much longer lengths (20 ft). Even in the longer lengths, the pipe segments are still much lighter than the comparable RCP segments; therefore much smaller lighter equipment is required for placing the pipe in the trench. In addition, more pipe can be delivered at a time, not only because more segments can be delivered at a time, but also because each length is longer. The longer lengths also lead to fewer joints and reduced leakage potential.

CLCMP has several other advantages. High material quality control can be maintained because the pipeline is manufactured in the factory, not in the field. Second, the installation is relatively fast because the pipe is delivered at the site ready for installation and backfill. The trench can be closed as soon as the pipe has been installed. Third, the concrete lining provides similar hydraulic characteristics to RCP, therefore, diameters of the pipe are similar to those of RCP. Finally, CLCMP is relatively thin and the outside diameter (OD) is only 2 inches larger than the inside diameter of 120-inch CLCMP (OD=122 inches). RCP, on the other hand, can range from 8 to 11 inches thick; for 120 inch class III RCP, the OD is 142 inches. In areas with a lot of utilities, 20 inches can be a significant addition to the pipeline OD and required trench width.

Several disadvantages also result from the flexible nature of CLCMP. First, backfill and compaction requirements must be much more stringent to prevent pipeline deflections from exceeding the allowable 5 percent. Both RCP and CLCMP will be backfilled and compacted in thin layers to 1 ft above the top of the pipe. However, CLCMP relies more heavily on proper backfill and compaction to handle and resist the loads than does RCP. In addition, if the backfill and compaction is not handled properly, and additional pipeline deflection is created beyond the allowable 5 percent, then the CLCMP concrete lining can be cracked, reducing the hydraulic ability of the pipeline; but worse yet, the aluminized coating can be cracked longitudinally, allowing corrosion attack from the soil side of the pipe. The life of the pipeline is greatly reduced if the aluminized coating is cracked.

CLCMP has several other disadvantages. First, CLCMP is a metal pipe and although the aluminized coating greatly extends the life of the steel, CLCMP is still not suitable for highly corrosive soil environments. The Cactus Road soils data for two borings showed evidence of slightly corrosive soils. The areas appeared to be localized but could be a problem (see discussion in section 4). Second, concrete lining cannot be used in an arched CMP except for very short segments where the coating is applied in-situ, by hand. Arched CMP is sometimes desirable for extreme loads or more efficient hydraulic characteristics. Third, there is still some concern in the industry about the lack of bond between the steel and concrete. This does not appear to be a problem either from a corrosion or hydraulic concern based on the studies performed to date.

A final significant concern about CLCMP is the anticipated life of the product. Studies have shown that the aluminized coatings worked well in nearly all soils and moisture conditions for at least 30 years. Due to minimal effects caused by corrosion on the 30-year old installations, it would not be unreasonable to expect the materials to last at least twice as long as that. However, the aluminized coating is too new to automatically assume it will last from 75 to 100 years. Once corrosion begins, it can be a very rapid process. Many local agencies have expressed concern about the life of the product. The Arizona Department of Transportation (ADOT) has restricted the use of CLCMP based on concerns about the life of the product. ADOT requires a material life of 75 years on storm drains in freeways and primary roads. The material life for secondary and minor roads are 50 and 25 years, respectively. ADOT does not feel there is sufficient data at this time to show that CLCMP will provide a 75-year life. Therefore, CLCMP is not allowed for freeway or primary road storm drains in lengths over 1,000 ft.. CLCMP is allowed for installations that only require a 50-year life.

Many cities in the valley have allowed CLCMP in limited locations, but only in smaller diameters and shorter installations. The largest CLCMP installed in the valley is 96 inches. None of the local CLCMP installations are over 10 years old, which is too soon to tell how local conditions will affect the conduit material.

3.3 Precast Box

Precast box conduits offer similar advantages as RCP and CLCMP in terms of high quality control and relatively rapid installation because the conduit material is prefabricated. Precast box conduits are also similar in nature to RCP in that the box is a rigid conduit and requires thin-layer compaction only to the top of the box in trench conditions. The design of the conduit itself withstands the soil loads above and adjacent to the box and does not require optimum trench backfill to resist deflection.

A precast box conduit has two major disadvantages. First, a good gasket was not available for the box joints until recently; therefore, leakage could be a problem in some installations. A few precast box conduits have been installed in the Phoenix area using a new gasket and leakage appears to no longer be a problem. Second, precast box conduits require more materials (rebar and concrete) per flow area in the smaller sizes than RCP. The increased material requirements leads to short lengths (due to weight), increased material cost, increased delivery cost and increased leakage potential due to frequent joints. However, precast box conduits are easier to install. Compaction of the haunches of a circular pipe is more difficult than the haunches of a square box. According to local manufacturers and contractors, the break-even point is about the 10 ft x 9 ft box or 120-inch diameter pipe; precast box conduits are competitive with RCP in the larger sizes but not in the smaller sizes.

3.4 Cast-In-Place (CIPP)

CIPP has been used extensively in the valley for smaller diameter applications and where utility interference has been negligible. CIPP is cast in trench using the trench walls and floor as part of the form and a special piece of equipment which places the (inside diameter split-ring forms) and pours the concrete. After sufficient drying, the forms are removed from the inside and the interior troweled smooth where necessary. This type of conduit is highly cost-effective and many contractors in the area have experience installing the smaller diameters. The nature of the pipe construction virtually eliminates pipe joints reducing leakage potential. With quick-setting concrete mixes, open trench times have been reduced and the trench can be backfilled within 24 to 48 hours.

The most significant disadvantage to CIPP is that the conduit is constructed in the trench in the field. Optimum field conditions and a reliable contractor along with rigid, careful specification and inspection are required to maintain quality control of the conduit construction. Soil conditions must be adequate to provide a good form for the bottom and sides of the conduit. If a soil is cobbley or unstable, wall thickness will vary and may not meet specification requirements or greatly increase material requirements and increase costs. The City of Phoenix will no longer allow installation of CIPP if the bedding is unsuitable without overexcavation and backfill to form the floor and walls of the trench. Soil conditions for Cactus Road indicate that significant cobbles may be encountered in the lower depths (over 15 ft) and therefore CIPP would not be a suitable conduit. Additional discussion can be found in section 4.

A second disadvantage, despite the use of quick-setting concrete, is the open trench installation time. CIPP can be installed at a similar rate to precast pipe when installing in areas with few utility interferences and few external connections. However, Cactus Road contains many utility crossings that will reduce the lengths of run and cause delays in construction and may require the use of precast conduits in these areas. There is also some concern about the structural integrity of large diameter CIPP. ADOT and the City of Phoenix, among other valley agencies, will not allow CIPP in diameters over 96 inches. Over half of the Cactus Road Storm Drain is larger than 114 inches.

3.5 Cast-In-Place Box (CIP Box)

CIP box conduits provide good structural characteristics and are used extensively as road crossings where strength is required or cover is minimal (e.g., freeways commonly use box culverts). CIP box construction follows several steps: the trench is excavated, the floor rebar cage is constructed, the floor poured, the wall and roof rebar cage is constructed, the forms are constructed for the walls and roof, and the walls and roof poured. Even with quick-setting concrete, it is still a tedious job to construct a CIP box culvert.

A 4,500-foot CIP box storm drain was recently constructed parallel to Interstate 10 in the City of Tempe. The upstream portion was 12 ft x 8 ft and the downstream portion was 16 ft x 8 ft (somewhat larger than the largest portion of the Cactus Road Storm Drain). The trench path was parallel to the freeway and unobstructed by all but a few utilities. Construction of this box culvert was very successful because of the large size (paddle wheel scrapers were used very economically to excavate the trench), 1/2 mile reaches could be opened at one time, there was no interference with either traffic patterns or existing utilities, the soils were suitable to support a box, and shoring was not required for trench walls. A quick-setting concrete mix was used for the walls and roof, which sped up construction to a 24-hour period and made construction almost like a slip-form operation. Wall and roof forms were set up in the morning with concrete poured at 2:00 p.m. and allowed to cure to the next morning, when the forms were moved to the next reach. The use of paddle wheel scrapers, long open reaches and quick-setting concrete all reduced construction time. However, construction still took 6 months for 4,500 ft. If the same techniques and subsequent construction time frame could be used on the Cactus Road storm drain, construction would take up to 2 years to complete; far longer than any of the other methods.

As stated above, CIP box conduits have good structural characteristics and, as in the case of CIPP, CIP box conduits are continuous with relatively little leakage problem. Quick-setting concrete mixes have reduced installation times over previously used concrete mixes but the installation time is still a drawback for high traffic areas. CIP box conduits are also constructed in the trench. Soil conditions affect quality control and a good contractor along with rigid specifications with strict field supervision is required to insure a quality conduit.

4. SOILS REPORT RECOMMENDATIONS AND IMPACT ON STORM DRAIN CONDUIT ALTERNATIVES

The field soils investigation included a site reconnaissance, subsurface exploration, and field resistivity testing. Thirty-five test borings were drilled to depths of 11 to 26 feet below the pavement section, with refusal encountered at some locations. Additional information about the field investigations and detailed information about each boring location has been published in the Thomas-Hartig and Associates, Inc. geotechnical report and distributed to the Flood Control District of Maricopa County, the City of Peoria and the City of Glendale. The following is only a summary of the results of that report as the findings impact the storm drain conduit alternatives.

Granular deposits were encountered at and above invert elevations in a majority of test borings. These granular deposits contain gravel and some cobbles and boulders and clean sand layers. Because of the coarse granular materials and potential for caving in, a shaped excavation for cast-in-place pipe may be difficult to impossible to construct. This soil property should not affect the other storm drain alternatives.

Existing surface soils are sandy clays and clayey sands, predominantly of medium plasticity. Undisturbed soils will demonstrate moderately low potentials for expansion. However, compaction of these soils could create high expansive pressures. Imported granular soils exhibiting low expansive potentials or granular site soils are recommended for all backfills along the sides of the storm drain pipe.

The soil along the alignment is fairly strong and the drain will be lighter than the soil it replaces. Low settlements (less than 1/4 inch) due to the construction related disturbance are anticipated and an allowable bearing capacity of 5,000 psf afforded structures and manholes.

Lateral earth pressures are 60 psf/ft for current groundwater conditions and 95 psf/ft for rising groundwater or trench flooded backfill conditions. Walls should be suitably braced during backfilling to prevent damage and excessive deflection.

All excavations should be braced or sloped to provide personnel safety and satisfy local safety code regulations. Maximum temporary cut slopes of 1/4 H:1V in sandy clay/clay clayey sand and 1H:1V in the granular soils are recommended.

Backfill compaction should be accomplished by mechanical methods. Water jetting or flooding of loose, dumped backfill must be prohibited.

Soluble salts, soluble sulfates, soluble chloride, pH and resistivity tests were conducted at various boring locations. The corrosion potential to concrete is low; Type II cement should be used for concrete in contact with soils. Relatively low resistivities (high conductivities) were encountered in only two test borings (sta. 89+00 and 99+00 approximately). The resistivity for sta. 89+00 was 1840 ohm-cm for 0-15 ft and 2630 ohm-cm for 0-25 ft. The resistivity of 1840 ohm-cm is close to, but above, the minimum 1500 ohm-cm for CLCMP and therefore may not be a problem. The resistivity for sta. 99+00 was 1520 ohm-cm for 0-15 ft and 1150 ohm-cm for 0-25 ft with a pH of 8.2 The resistivities are low for this site but the pH is acceptable for aluminized coatings on CLCMP. In addition, a moderate potential for corrosion of buried unprotected metal conduits is indicated in areas where soil moisture content is high. Experienced corrosion specialists should review data for recommendations on metal conduits.

5. COST COMPARISON OF STORM DRAIN CONDUIT ALTERNATIVES

5.1 Conduit Construction Cost

Local suppliers and contractors were contacted to determine an estimated cost for RCP, CLCMP, Precast Box and CIPP. The current edition of The Richardson Rapid System General Construction Estimating Standards was used to determine cost of earthwork and installation of precast conduits. It was not possible to exactly determine the quantity of concrete, rebar and labor required to construct a CIP Box, therefore, prorated costs for these items were used from the City of Tempe box culvert discussed in section 3.5 above. Table 2 lists the estimated total cost and the estimated cost per lineal foot for each type of conduit. These costs do not include the cost of the numerous fittings/structures that will be required to connect the Cactus Road storm drain to collector basins and stubouts to future storm drain laterals. These costs also do not include the cost of rerouting or accommodating the existing utilities or the traffic control problems.

At this point, the CIPP alternative is the least expensive followed in order by CLCMP, RCP, CIP Box and Precast Box. As stated in section 3.4 and 3.5, utilities and numerous specially constructed inlets will greatly affect the cost of the cast-in-place conduits and raise their unit prices. In addition, these conduits are constructed in the field and special features will increase the construction time. Special structures affect the cost of RCP, CLCMP, and Precast Box conduits, but not as much. Secondly, construction time to install prefabricated special fittings is much faster than construction and installation of cast-in-place special fittings because the construction takes place in the factory and only installation is required in the field.

5.2 Conduit Operation and Maintenance Cost

Small conduits are subject to occasional plugging that would require occasional maintenance. The Cactus Road storm drain is a very large diameter conduit and plugging is not likely to be a problem. However, sediment load can accumulate in large conduits affecting the hydraulic characteristics and the ability of the pipeline to carry the water it was designed for. This can be accommodated in the design analysis and, if necessary, slightly oversize the conduit. The greater impact to the conduit would be the material life, if the sediment load were to erode the invert of the pipeline. In the Phoenix area, the sediment load of storm drains is not a significant problem, either in terms of quantity of sediment deposition or invert erosion. In addition, the Cactus Road storm drain is not a steeply-sloped conduit which is a leading cause of invert erosion problems. However, the storm drain has been sized for a minimum velocity of 5 fps during the 10-year storm to provide a flushing action and reduce any sediment build up.

Periodic inspection would be suggested for large diameter pipelines to insure that the interior of the pipeline is in good condition. These inspections should be more frequent (e.g., annual inspection) during the early years for the flexible CLCMP conduit and for CIPP to insure that these pipelines were properly installed and backfilled. CLCMP deflections should be monitored both when the pipe is first installed and during the periodic inspections. The inside diameter measurements of CIPP should be taken after construction prior to acceptance of the conduit by the Cities of Peoria and Glendale, and the Flood Control District of Maricopa County to insure proper installation of the conduit.

Costs for O&M have not been calculated because the cost of annual inspections is relatively nominal and no other maintenance is anticipated to be required for the main storm drain. Some maintenance of the catch basins may be required but the cost of this maintenance will be equal for all alternatives and therefore catch basin maintenance has not been estimated or included.

6. PRELIMINARY DESIGN RECOMMENDATIONS

Table 3 summarizes the information on each of the alternatives in tabular form.

Reinforced concrete pipe is obviously suitable for the Cactus Road storm drain and it is not the most expensive conduit. There are sufficient companies in the area to ensure competitive bidding and a reasonably good price.

Competitive bidding is improved, however, if other alternatives can be allowed. CLCMP offers many of the same advantages of RCP with a potential, substantial cost-savings. However, the design criteria calls for a 75- to 100-year conduit material life and CLCMP has not been shown to have an extended product life. In addition, CLCMP is a flexible pipeline which will require excellent field quality control for backfill and compaction. To verify that this is accomplished, a thorough inspection and testing program will be required. If the pipeline deflection is not kept below 5 percent, then the aluminized coating will likely crack resulting in corrosion and probable shortening of the pipeline life. CLCMP has not been installed anywhere in the valley in this size and quantity, and rarely installed anywhere in the 120-inch diameter. Major agencies, including ADOT, limit the use of CLCMP. Installation of CLCMP in this size and quantity is a risk as compared to more proven alternatives. We do not recommend that this project be a "test case" for large diameter CLCMP.

The precast box conduit was the most expensive alternative; however, the earthwork costs for the precast box were the lowest of all of the alternatives. It is not anticipated that lower earthwork costs can bring the precast box into competitive bidding for this size conduit at this time, particularly if cement slurry or other slurry backfills are used.

CIPP and CIP box are also not considered viable alternatives. CIPP is not recommended by other local agencies in sizes over 96 inches. But more importantly, the soils report does not recommend CIPP in any size due to the cobbley, unstable nature of the trench form. CIP box is not recommended because of the extensive time requirements to construct and the resulting traffic difficulties.

Only RCP appears to meet all the design criteria and soils recommendations, yet still be cost-competitive due to the number of local suppliers. RCP is a proven material and can be relied on to perform well.

TABLE 1
Conduit Material Physical Characteristic Comparison
Cactus Road Storm Drain - Flood Control District of Maricopa County
November 1992

	84-Inch				120-Inch			
	RCP Class III[a]	RCP Ameron[b]	CLCMP 5 x 1 14 ga[c]	Precast Box 7'x6'[d]	RCP Class III[a]	RCP Ameron[b]	CLCMP 5 x 1 14 ga[c]	Precast Box 10' x 9'[d]
Pipe Length, ft	6	12	20	7.5	6	12	20	7.5
Approx Weight, lb/ft	2,409	2,090	318	3,066	4,716	4,830	542	5,520
Approx Weight per Piece, lb	14,454	25,080	6,360	22,995	28,296	57,960	10,840	41,400
Outside Diameter, in	100	100	86	8.33' x 7.33'	142	142	122	11.67' x 10.67'
Maximum Allowable Fill, ft	17	N/A	45	N/A	18	N/A	54	N/A
Truckloads per 1,000 ft of Pipe	50	N/A	25	N/A	99	N/A	25	N/A
Joints per 1,000 ft of Pipe	166	N/A	49	N/A	166	N/A	49	N/A

[a]information provided by Contech Construction Products, Inc.
[b]Information provided by Ameron
[c]Information provided by Contech Construction Products, Inc.
[d]Information provided by Gifford-Hill

N/A = Information not available or not provided

Source: SFC Engineering Company, June 1992

TABLE 2
Alternative Conduit and Section Material Cost Estimate
Cactus Road Storm Drain - Flood Control District of Maricopa County
November 1992

	Reinforced Concrete Pipe	Concrete Lined Corrugated Metal Pipe	Precast Box	Cast-In-Place Pipe	Cast-In-Place Box
Total Cost ($)	6,222,000	5,032,000	7,599,000	4,743,000	6,273,000
Unit Cost ($/lin ft)	366	296	447	279	369

Source: SFC Engineering Company, June 1992

TABLE 3 (Page 1)
Summary of Alternative Conduit Section and Material Advantages and Disadvantages
Cactus Road Storm Drain - Flood Control District of Maricopa County
November 1992

ADVANTAGES	DISADVANTAGES
REINFORCED CONCRETE PIPE (RCP)	
Excellent prior history Precast, good quality control Many local manufacturers, good availability Long Life Relatively fast installation Invert erosion seldom a problem	Short lengths (approximately 6 ft in 120-inch diameter) Special fabrications expensive Third highest material cost Heaviest pipe weight of other precast materials; large heavy equipment required to install the pipe
CONCRETE LINED CORRUGATED METAL PIPE - (CLCMP)	
CMPCL has similar hydraulic properties as RCP Comes in longer lengths, fewer joints Lighter pipe, lower shipping, delivery, and installation equipment costs Lower cost for special fabrications Prefabricated, good quality control Relatively fast installation Smaller outside diameter, smaller trench width Second lowest material cost	Unproven life of material Deflections can cause cracks in concrete lining Backfill/bedding is critical for structural stability Not suitable for corrosive or unstable soils Cannot arch concrete lined CMP Industry still has some concerns about lack of bond between steel and concrete

TABLE 3 (Page 2)
Summary of Alternative Conduit Section and Material Advantages and Disadvantages
Cactus Road Storm Drain - Flood Control District of Maricopa County
November 1992

ADVANTAGES	DISADVANTAGES
PRECAST BOX	
Prefabricated, good quality control Structurally sound Relatively fast installation	Gasket and leakage problems at higher heads Most expensive material cost
CAST-IN-PLACE PIPE (CIPP)	
Lowest material cost	Trench is open a long time (pour 300 to 600 ft/day and backfill 24 to 48 hours after pour) Field manufacture can lead to a lack of quality control in field Cannot be used in all soil conditions (rocky or unstable soil) and CIPP is not recommended for many areas of the Cactus Road storm drain Utility conflicts cause forming problems
CAST-IN-PLACE BOX	
Good structural characteristics	Field manufacture can lead to lack of quality control in field Trench is open a long time (longer than CIPP) Fourth most expensive construction cost Heavy demand for field supervision and inspection to control reinforcing installation, etc.