Technical Memorandum

To: Kathy Arnold

From: Francisco Barrios, P.E. and Greg Hemmen, P.E.

Company: Rosemont Copper Company

Re: Rosemont Pit Diversion Channel Design

CC: David Krizek, P.E. (Tetra Tech)

Date: April 05, 2010

Doc #: 103/10-320828-5.3

1.0 Introduction

This Technical Memorandum discusses the hydrologic and hydraulic calculations performed for the Pit Diversion Channel (Channel) as part of the site water management for the Open Pit area at the proposed Rosemont Copper Project (Project) in Pima County, Arizona. The Channel is located along the western extents of the Open Pit area as shown on Figure 1 and will be constructed early in the life of the Project. The Channel will also incorporate a Pit Electrical Loop Road over a portion of the Channel alignment. This Channel will be a permanent structure and was designed to pass the Local Probable Maximum Precipitation (PMP) storm event from its contributing basins.

Should modifications occur to this design, the general stormwater analysis presented herein would still be applicable assuming the configuration of basin areas and channel lengths were comparable to those analyzed.

In general, the Pit Diversion Channel will route stormwater from basins west and south of the Open Pit into the upper part of the Barrel Canyon drainage. At the end of the Channel, a large multi-plate culvert will be constructed to pass storm flows into the canyon. The Channel design also incorporates a drop structure and a large fill area.

During the early years of the Project, storm runoff from the Channel will enter Barrel Canyon and flow, unimpeded, down the drainage. Over time, placement of waste rock in the Waste Rock Storage Area will confine the flows. The design of the stormwater management features associated with the Waste Rock Storage Area takes storm flows from the Pit Diversion Channel into account.

Perimeter Containment Basins (PCAs) are located between the toe of the Waste Rock Storage Area and a natural ridgeline. The PCAs are designed to manage stormwater generated by a General PMP event from the Waste Rock Storage Area and from the Pit Diversion Channel. Stormwater management details for the Waste Rock Storage Area are provided in the Technical Memorandum titled Rosemont Waste Rock Storage Area Stormwater Management (Tetra Tech, 2010c).

The design method for the Pit Diversion Channel was based on the Natural Resources Conservation Service (NRCS) curve number procedure to estimate the peak stormwater runoff. This method, along with Manning’s open-channel flow equation, was used to calculate the
proper channel sizing and to design the drop structure and culvert. The methods used for the analysis are discussed in greater detail in the Technical Memorandum titled *Rosemont Hydrology Method Justification* (Tetra Tech, 2010a).

2.0 Hydrologic Method Overview (NRCS Method)

The NRCS method was developed for general hydrologic analysis and allows for various storm distributions and durations to be analyzed. The method is applicable to the analysis of large complex watershed systems, such as mining sites, where landscape conditions may change over time. Therefore, the NRCS method was selected for this analysis based on the information available and on the expectations for the analysis.

The analysis was performed using HEC-HMS, a hydrologic modeling software package developed by the U.S. Army Corps of Engineer’s (USACE). HEC-HMS incorporates the NRCS method and allows for the analysis of complex/integrated systems (i.e., multiple sub-basins, reservoir, and channel routing, etc.).

The primary input variables for determining the peak flow associated with stormwater runoff are:

- Precipitation;
- Storm distribution;
- Curve number;
- Basin delineation or area; and
- Time of concentration or lag time.

HEC-HMS uses these parameters and the NRCS unit hydrograph to estimate runoff after appropriate losses (i.e., infiltration). It is also used to develop a specific basin’s relationship between runoff versus time, presented as a hydrograph curve. The area under a hydrograph curve represents the basin’s expected total runoff volume and the apex of the hydrograph curve represents the basin’s estimated peak flow rate.

The estimated values for peak runoff were used for the hydraulic design of the Pit Diversion Channel and its corresponding elements. These input variables are presented in the following sections and are discussed in greater detail in the Technical Memorandum titled *Rosemont Hydrology Method Justification* (Tetra Tech, 2010a).

2.1 Precipitation

Precipitation for the PMP storm event was estimated utilizing the procedures outlined in the Hydrometeorological Report No. 49 (HMR 49) published by the National Oceanic Atmospheric Administration (NOAA). The coordinates used to obtain precipitation data for the Project site were 31.862 N 110.692 W at an elevation of 4,429 feet above mean sea level (amsl), which is northeast of the Pit Diversion Channel.
2.2 Rainfall Storm Distributions

The NRCS method allows for many precipitation patterns to be applied to the watershed. The storm events considered for estimating peak runoff were the 6-hour Local PMP Distribution and the 72-hour General PMP Distribution. The Technical Memorandum titled *Rosemont Hydrology Method Justification* (Tetra Tech, 2010a), stated that a Local PMP event generates less volume than a General PMP, but larger peak flows because of its shorter duration and correspondingly higher rainfall intensities. For the Project site, a Local PMP storm is estimated to generate 15.0 inches of rainfall in six (6) hours. The General PMP event is estimated to generate 18.9 inches of rainfall over 72 hours.

The Local PMP storm event was selected as the design event for sizing the Pit Diversion Channel. Table 1 summarizes the Local PMP storm event and the General PMP storm event.

<table>
<thead>
<tr>
<th>Table 1 Design Storms</th>
</tr>
</thead>
<tbody>
<tr>
<td>Parameters</td>
</tr>
<tr>
<td>Distribution</td>
</tr>
<tr>
<td>Duration (hours)</td>
</tr>
<tr>
<td>Precipitation (inches)</td>
</tr>
</tbody>
</table>

2.3 Rainfall Losses – Curve Number

The NRCS developed a curve number (CN) procedure for estimating runoff from storm events. The curve number procedure is incorporated in this analysis.

Rainfall losses depend primarily on soil characteristics and land use (surface cover). The NRCS method uses a combination of soil conditions and land use to assign runoff factors (curve numbers) that represent the runoff potential of a soil type (i.e., the higher the curve number, the higher the runoff potential).

The NRCS classifies soils as “A”, “B”, “C”, or “D”, based on their hydrologic soil group to determine the runoff potential. Type “A” soils, such as sandy soils, have a very low runoff potential. Type “D” soils, such as heavy clay and/or shallow, rocky soils, have a very high runoff potential. Soil groups at the Project site were determined from the NRCS Soil Survey Geographic Database (SSURGO) data set. The main soils present near the Pit Diversion Channel and within the Project site are of type B, C, and D, which are further defined in Table 2.
Table 2  Hydrologic Soil Groups

<table>
<thead>
<tr>
<th>Hydrologic Soil Group</th>
<th>Description*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type B (Moderately low runoff potential)</td>
<td>These soils have a moderate infiltration rate when thoroughly wetted. They chiefly are moderately deep to deep, moderately well drained to well drained, soils that have moderately fine to moderately coarse textures. They have a moderate rate of water transmission (4 to 8 mm/hr), and are generally described as silty loam, and loam.</td>
</tr>
<tr>
<td>Type C (Moderately high runoff potential)</td>
<td>These soils have a slow infiltration rate when thoroughly wetted. They chiefly have a layer that impedes downward movement of water or have moderately fine to fine texture. They have a slow rate of water transmission (1 to 4 mm/hr), and are generally described as sandy clay loam.</td>
</tr>
<tr>
<td>Type D (High runoff potential)</td>
<td>These soils have a very low infiltration rate when thoroughly wetted. They chiefly consist of clay soils that have a high swelling potential, soils that have a permanent high water table, soils that have a claypan or clay layer at or near the surface, and shallow soils over nearly impervious material. They have a very slow rate of water transmission (0 to 1 mm/hr), and are generally described as clay loam and silty clay loam.</td>
</tr>
</tbody>
</table>

* Descriptions obtained from Pima County Regional Flood Control District’s PC-Hydro User Guide.

The curve number for the Pit Diversion Channel’s contributing basins was calculated using GIS data layers available for the hydrologic soil groups within the area and land use layers obtained from the Pima County Department of Transportation: Geographic Information Services Division. Based on the land use layers, the entire watershed for the Pit Diversion Channel falls under the arid range/desert shrub categorization classified in fair condition.

A curve number of 85 was calculated for the Pit Diversion Channel’s contributing basins. The curve number is based upon soil types, land use, an Antecedent Moisture Condition (AMC), and the related initial abstraction of 0.35 inches. The AMC accounts for the preexisting moisture conditions of the soils before the storm event. The initial abstraction is the total amount of precipitation in inches that is infiltrated and absorbed into the soil before runoff begins. The initial abstraction is developed in the following sections.

2.4  Drainage Basin Delineations

Three (3) separate drainage basins, each delineated with their unique contributing watershed, were analyzed as part of the design. These areas are shown on Figure 1.

2.5  Rainfall Runoff Excess

The NRCS method estimates rainfall runoff excess as a function of cumulative precipitation, soil cover, land use, and AMC using the following relationships:

\[
Pe = \frac{(P - I_a)^2}{P - I_a + S}
\]

\[
S = \frac{1000}{CN} - 10
\]
Where:

- \( Pe \) = the accumulated precipitation excess, in inches;
- \( P \) = the accumulated precipitation depth, in inches (Local PMP storm event);
- \( S \) = the maximum soil water retention parameter, in inches;
- \( Ia \) = the initial abstraction, in inches; and
- \( CN \) = the curve number.

From an analysis of results for many small experimental watersheds, NRCS developed an empirical relationship between the initial abstraction and the maximum soil water retention parameter given by the following expression:

\[
Ia = 0.2 \times S
\]

Therefore, the determination of accumulated precipitation excess can be rewritten as:

\[
Pe = \frac{(P - 0.2S)^2}{P + 0.8S}
\]

2.6 Time of Concentration / Lag Time

The time of concentration (Tc) is the travel time for a flood-wave to travel from the hydraulically most distant point in the basin to the outlet during a period of the most intense rainfall excess. The time of concentration was determined by considering the most hydraulically distant flow path for each basin.

HEC-HMS requires a lag time that is equal to 0.6*Tc. The lag time equation was developed from agricultural watershed data and has been adapted to small urban basins, less than 2000 acres in size, where the equation is defined as:

\[
Lg = \frac{L^{0.8} (S + 1)^{0.7}}{1900y^{0.5}}
\]

Where:

- \( Lg \) = the lag time, in hours;
- \( L \) = the hydraulic length or the distance of the longest watercourse in the watershed, in feet;
- \( y \) = the average watershed slope, in percent; and
- \( S \) = the maximum soil water retention parameter in terms of the curve number noted before, in inches.

The unique characteristics required to determine each basin’s lag time were developed by utilizing Autodesk Land Desktop 2009. The lag times were then used in HEC-HMS to establish
the peak flows as the basis for the Channel design. Table 3 presents the parameters used to calculate the lag time.

<table>
<thead>
<tr>
<th>Basin ID</th>
<th>Basin Area (mi²)</th>
<th>Length (ft)</th>
<th>Slope (%)</th>
<th>CN</th>
<th>Lg (min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>PD-1</td>
<td>0.2029</td>
<td>5,009</td>
<td>51.55</td>
<td>85</td>
<td>8.171</td>
</tr>
<tr>
<td>PD-2</td>
<td>0.0474</td>
<td>3,436</td>
<td>58.00</td>
<td>85</td>
<td>5.697</td>
</tr>
<tr>
<td>PD-3</td>
<td>0.0907</td>
<td>4,806</td>
<td>61.00</td>
<td>85</td>
<td>7.267</td>
</tr>
</tbody>
</table>

* Parameters obtained from Autodesk Land Desktop 2009

2.7 Routing Method

In general, the Pit Diversion Channel is designed with an upper channel section sloped at 1% before entering the drop structure sloped at 25%. The lower channel section returns to the 1% slope after the drop structure and its outlet apron. The channel then widens out over the fill area before entering into the culvert.

Channel routing is the term applied to the NRCS method to account for the effects of channel storage on the runoff hydrograph as the storm event moves through a channel reach. Channel routing is used to translate and attenuate an upstream runoff hydrograph into a downstream hydrograph during the specific design storm event. The routing procedure has two (2) components – the routing method and the physical channel characteristics. The drop section of the Channel is sloped at 25% and the Kinematic Wave method was employed for routing of this section. The Muskingum-Cunge method was used for the routing of the remaining channel sections which are sloped at 1%.

The Muskingum-Cunge method was selected over the Kinematic Wave method for the flatter portions since it is intended for slopes less than 10%. The main advantage of these routing methods is that the relative coefficients are evaluated from physical channel characteristics and can be determined without existing flood hydrograph data. The physical channel characteristics used in the routing are presented in Table 4.

<table>
<thead>
<tr>
<th>Reach ID</th>
<th>Length (ft)</th>
<th>Slope (%)</th>
<th>Manning's n</th>
<th>Shape</th>
<th>Bottom Width (ft)</th>
<th>Side Slope (H:V)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reach-1</td>
<td>1,098</td>
<td>1.0</td>
<td>0.035</td>
<td>Trapezoidal</td>
<td>20</td>
<td>2:1</td>
</tr>
<tr>
<td>Reach-2</td>
<td>1,858</td>
<td>1.0</td>
<td>0.035</td>
<td>Trapezoidal</td>
<td>20</td>
<td>2:1</td>
</tr>
<tr>
<td>Reach-3</td>
<td>1,300</td>
<td>25.0</td>
<td>0.028</td>
<td>Trapezoidal</td>
<td>20</td>
<td>2:1</td>
</tr>
</tbody>
</table>

* Parameters obtained from Autodesk Land Desktop 2009

As shown on Figure 1, the channel section downstream of Junction-3 and upstream of Junction-2 was broken into two (2) reaches, where Reach-3 corresponds to the Pit Diversion Channel's drop structure starting at Junction-3 and Reach-2 represents the typical lower channel section sloped at 1% after the drop structure. Although the Pit Diversion Channel widens downstream of Junction-2, the typical lower channel section was conservatively used to analyze Reach-1.
3.0 Hydraulic Method Overview (Manning’s Formula)

The hydraulic analysis used Manning’s open-channel flow equation, with cumulative peak flow rates, to size the sections of the Pit Diversion Channel. Manning’s formula for open-channel flow is as follows:

\[ Q = \frac{1.486 A \cdot R^{2/3} \cdot S^{1/2}}{n} \]

Where:

- \( Q \) = The channel flow rate, in cubic feet per second (cfs);
- \( A \) = The cross sectional area of flow, in square feet (ft²);
- \( R \) = The hydraulic radius of flow, in feet;
- \( S \) = The longitudinal slope of the flow path for the channel, in feet/foot; and
- \( n \) = Manning’s roughness coefficient for the channel, unitless.

The following equations for the area and the hydraulic radius of the flow were obtained from the properties of triangles. The depth of flow was checked using these relationships to verify that the specific channel section was properly designed for safety:

\[ A = \frac{1}{2} (m_1 y^2 + m_2 y^2) \]

\[ R = \frac{\sqrt{m_1^2 y^2 + m_2^2 y^2}}{\sqrt{m_1^2 y^2 + y^2} + \sqrt{m_2^2 y^2 + y^2}} \]

Where:

- \( A \) = the cross sectional area of flow, in square feet (ft²);
- \( R \) = the hydraulic radius of flow, in feet;
- \( m_1 \) = the side slope of the channel;
- \( m_2 \) = the side slope of the channel; and
- \( y \) = the depth of flow, in feet.

4.0 Hydrologic and Hydraulic Analysis Results

Table 5 summarizes the cumulative peak runoff results from the hydrologic analysis using the 6-hour Local PMP storm event for the design of Pit Diversion Channel.
Table 5  Summary of Pit Diversion Channel Analysis

<table>
<thead>
<tr>
<th>Concentration ID</th>
<th>Peak Flow Rate (cfs)</th>
<th>Maximum Flow Depth (ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Junction-1</td>
<td>4,899</td>
<td>7.47</td>
</tr>
<tr>
<td>Junction-2</td>
<td>1,971</td>
<td>5.82</td>
</tr>
<tr>
<td>Junction-3</td>
<td>1,348</td>
<td>4.76</td>
</tr>
</tbody>
</table>

In general, the upper Channel section, upstream of Junction-3, is designed to convey the peak flow with:

- A bottom width of 20 feet;
- A depth of 7.5 feet;
- 2H:1V (Horizontal to Vertical) side-slopes; and
- Sloped at one (1) percent (%).

A cross section of the upper Channel section is shown on Figure 2, Section A.

The maximum depth of the peak flow is expected to be about five (5) feet in the Channel prior to entering the drop structure at Junction-3. This allows for about 2.5 feet of freeboard in the current preliminary design shown on Figures 1 and 2. Channel dimensions may be modified to achieve a minimum freeboard of one (1) foot.

Similarly, the Channel’s drop structure after Junction-3 is designed to convey the peak flow with:

- A bottom width of 20 feet;
- A depth of 7.5 feet;
- 2H:1V side-slopes; and
- Sloped at 25%.

A cross section of the drop structure is shown on Figure 2, Section B.

The maximum depth of the peak flow is expected to be about two (2) feet in the drop structure. This allows for about 5.5 feet of freeboard in the current preliminary design shown on Figures 1 and 2.

This increases the flow velocity and decreases the flow depth in the drop structure. The drop structure terminates with an outlet apron with:

- A bottom width of 20 feet;
- A bottom length of 85 feet;
- A depth of 11.5 feet;
- 2H:1V side-slopes; and
- Sloped at 0%.

The outlet apron is designed to dissipate the flow velocity after the drop structure.

After the outlet apron, the lower Channel section, upstream of Junction-2, is similar to the upper Channel section with:

- A bottom width of 20 feet;
- A depth of 8.5 feet;
- 2H:1V (Horizontal to Vertical) side-slopes; and
- Sloped at 1%.

A cross section of the lower Channel section is shown on Figure 2, Section C.

The maximum depth of the peak flow for this Channel section is about six (6) feet, with 2.5 feet for freeboard near Junction-2 based on the preliminary design.

Just prior to Junction-2 and leading to Junction-1, the lower Channel section widens to:

- A bottom width of 30 feet;
- 3H:1V side-slope toward the downstream side of the compacted fill embankment;
- A 1% side-slope swale on the upstream side of the fill;
- A depth of 9.5 feet; and
- Sloped at 1%.

A cross section of the lower Channel section between Junction-2 and Junction 1 is shown on Figure 2, Section D.

The maximum depth of the peak flow for this Channel section is about 3.5 feet, with six (6) feet for freeboard based on the preliminary design. The section is designed to convey the expected increase in cumulative peak flow.

Before entering into the culvert located near Junction-1, the Channel transitions back to a trapezoidal configuration with:

- A bottom width of 30 feet;
- A depth of 9.5 feet;
- 3H:1V side-slopes; and
- Sloped at 1%.

A cross section of the Channel near Junction-1 is shown on Figure 2, Section E.
The maximum depth of the peak flow at Junction-1 just prior to entering into the culvert is estimated to be about 7.5 feet, which allows for about two (2) feet of freeboard based on the preliminary design to convey the peak flow into the culvert inlet.

4.1 Pit Diversion Drop Structure

The Pit Diversion Channel’s drop structure located downstream of Junction-3 is about 1,300 feet in length with:

- A bottom width of 20 feet;
- A depth of 7.5 feet;
- 2H:1V side-slopes; and
- Sloped at 25%.

The Channel transitions to a flat outlet apron at the base of the drop structure that is about 100 feet in length with:

- A bottom width of 20 feet;
- A depth of 11.5 feet; and
- 2H:1V side-slopes.

The drop structure will be armored to protect the structure from the potential for erosion and to attenuate the energy generated from the peak storm event. The armor will consist of the following from bottom to top:

- A prepared subgrade;
- A geotextile;
- A minimum of six (6) inches of angular drainage rock;
- A geogrid for additional shear strength; and
- The entire drop structure, including the bottom and side-slopes, will be lined with Contech ArmorFlex® articulated concrete block that is connected in sheets by steel cable.

The outlet apron will be constructed in the same manner, with more robust Contech Ajacks® concrete block armoring over about three (3) inches of drainage rock for the energy dissipation. Attachment 1 provides recommendations to achieve proper erosion control for the drop structure design.
4.2 Pit Diversion Culvert

The final discharge point of the Pit Diversion Channel is at Junction-1 and is constrained by a natural ridge. A steel, low profile, arch-shaped, 180 feet long, multi-plate culvert will be installed at this location to pass storm flows into the upper portion of Barrel Canyon. The design of the steel culvert is a low profile arch shape that is:

- 16.5 feet tall;
- 29.5 feet wide; and
- sloped at 3%.

The culvert was hydraulically analyzed to determine its capacity to safely convey the peak flow and to verify that the inlet and outlet controls are properly designed. Attachment 2 contains the corresponding calculations and recommendations for the culvert design.

The existing natural ridge will be excavated along the culvert’s alignment with a bottom width of about 40 feet and side-slopes at angle-of-repose. The culvert will be installed on the following prepared foundation (from bottom to top):

- A prepared subgrade;
- A four (4) foot thick run-of-mine (ROM) riprap layer across the width of the excavation; and
- A loose soil cushion layer will be placed between the riprap and the culvert.

The culvert will then be installed along its alignment with recompacted fill material placed around and over the culvert to a maximum cover of five (5) feet according to the manufacturer’s guidelines. An access road will pass over this culvert location.

The inlet of the culvert will be armored with about a four (4) foot thick and 20 foot long layer of ROM riprap for erosion protection and for energy dissipation against the anticipated scouring velocities from the peak storm events. The inlet will be constructed with wingwalls designed to funnel the peak flow into the culvert.

The outlet of the culvert will be armored with about a four (4) foot thick and 100 foot long layer of ROM riprap and will be constructed with wingwalls designed for erosion protection and energy dissipation.

As an alternative, the multi-plate culvert may be replaced with a channel cut and a light vehicle bridge.

5.0 Conclusion

Based on the analysis and the preliminary design results discussed herein, the Pit Diversion Channel, drop structure, and culvert are capable of safely conveying the estimated stormwater runoff generated from the Local PMP design storm event.
6.0 References


FIGURES
ATTACHMENT 1
DROP STRUCTURE RECOMMENDATIONS
Gregory Hemmen, P.E.
Tetra Tech
1750 SW Harbor Way, Suite 400 | Portland, OR 97201

Subject: Rosemont Channel – Armorflex Articulated Concrete Block

Greg;

Thank you for your continued interest in CONTECH Construction Products mine solutions. The following information and attached documents is in response to your inquiry regarding channel protection for Rosemont Mine in the Tucson, AZ area.

The information provided is preliminary, additional information will be required for final sizing/selection of products as well as quantities. The quote at the end is preliminary only and does not constitute a price offering by Contech. The quote would be similar to what a contractor would see if it were to bid today and does not include any material escalators (price of concrete rising/falling in the next year nor does it account for fluctuation in steel prices).

There will be some additional work and discussion that needs to happen between Tetra Tech and CONTECH but based on what you provided in our discussion on 3.30.2010, the following should be fairly close to accurate.

Should you have additional comments or questions, do not hesitate to contact me.

Sincerely,

Richard Shelton
Mine Market Manager

Cc: Clayton Fawcett
Keith Brooks
Gene Zande
We worked off the following information to determine the proper block size:

- 1,500 cfs
- 25% bed slope
- 2:1 Side Slopes
- 26’ bed width (request was for 20’, however, 26’ is best we can do, currently)

Based on this information we are pleased to offer our Class 70 Tapered Articulated Concrete Block System (ACB) (please reference table below for pricing and approximate quantities).

Please note that the quantities are approximate based off preliminary information provided. We can also provide design calculations for the Armoflex should you require that information. Depth of channel needs to be discussed further. Channel alignment on Armorwedge bears further discussion.

When you review the table note that the acronyms are meant to read as follows 70 T = Armorflex Class 70 Tapered, and AW = ArmorWedge

*All quantities and material costs are estimates. Price reflects material costs only (no installation). Kindly pay particular attention to Note 4 beneath the table.

<table>
<thead>
<tr>
<th>Bottom width in feet</th>
<th>L Side Slope 2:1 w/ turndown – assume 7’ depth</th>
<th>R Side Slope @ 2:1 w/ turn down – assume 7’ depth</th>
<th>Total length of mat</th>
<th>Channel Length</th>
<th>Total sf</th>
<th>Block Class</th>
<th>~ SF Price Delivered</th>
<th>~ total price</th>
<th>Factor of Safety (FOS)</th>
</tr>
</thead>
<tbody>
<tr>
<td>26</td>
<td>16</td>
<td>16</td>
<td>58</td>
<td>1,300</td>
<td>75,400</td>
<td>70T</td>
<td>$x.xx</td>
<td>$xx,xxx</td>
<td>1.5</td>
</tr>
<tr>
<td>22</td>
<td>16</td>
<td>16</td>
<td>54</td>
<td>1,300</td>
<td>70,200</td>
<td>70T</td>
<td>$x.xx</td>
<td>$xx,xxx</td>
<td>1.5</td>
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<tr>
<td>22</td>
<td>16</td>
<td>16</td>
<td>54</td>
<td>1,300</td>
<td>70,200</td>
<td>AW</td>
<td>$x.xx</td>
<td>$xx,xxx</td>
<td>1.5+</td>
</tr>
</tbody>
</table>

**Note 1:** The Tapered and ArmorWedge block offered above is with the ACB, site specific fabric, delivery and Tensar BX 1100. We have not priced the cost of the 6” drainage medium underneath the block.

**Note 2:** Once channel subgrade is prepped, assume 5,000 – 12,000 square feet installed per day for the tapered Armorflex and 1,500-2,000 square feet per day for the ArmorWedge (which is handplaced only).

**Note 3:** Armorflex brochure follows this proposal with all dimensions (in email, as a separate attachment).

**Note 4:** Bottom width 22’ (line #2 of the table, is based upon the actual discharge cfs of 1,350 as stated in our conversation on 3.30.2010). Bottom width of actual discharge reduces bottom width of channel but did not change the sizing of the block.
STILLING BASINS

Previous data was supplied on 2.9.2010 to Ronson Chee of your Tucson office. We would be pleased to continue this conversation regarding various solutions for energy dissipation at the site.

Sample photos and projects:

Class 50 Tapered Block in a copper mine in Arizona (confidentiality agreements prevent from naming the mine)

![Image of Excavator tramming the materials up side road, Spreader Bar used for placing, 28.33% grade in a copper mine, 2 block turndown trench, 2:1 side slopes]

Armorwedge in a steep application – handles up to 43 fps
Armorflex to Ajax transition | 24” Ajax installed | 24” Ajax transition to rip rap
* note the concrete wedge | *Sits on 3” drainage medium | Easy transition
* 4500 cfs at the transition point | *Dissipates energy

Brochure Details (4 page) – separate brochure to follow via email
A sequencing sheet that a contractor will receive.

<table>
<thead>
<tr>
<th>Mat #</th>
<th>Unit Wt lbs/sq.ft.</th>
<th>Mat Length max (ft)</th>
<th>Mat Length min (ft)</th>
<th>Mat Width max (ft)</th>
<th>Mat Width min (ft)</th>
<th>Mat Weight (lbs)</th>
<th>Total Mat Coverage (sq.ft.)</th>
</tr>
</thead>
<tbody>
<tr>
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Additional information for your bid documents and/or contractor.
### ArmorFlex® Unit Specification

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<tr>
<th>Concrete Block Class</th>
<th>Open/Closed Cell</th>
<th>Nominal Dimensions (L x W x H)</th>
<th>Gross Area/Unit (sq. ft.)</th>
<th>Block Weight (lbs)</th>
<th>lbs/sq. ft.</th>
<th>Open Area %</th>
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**High Velocity Application Block Classes**

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<th>Block Weight (lbs)</th>
<th>lbs/sq. ft.</th>
<th>Open Area %</th>
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**ArmorFlex® Tapered Series - Cross Section**

- **Top of Slope - Standard Detail**
- **ArmorFlex® Open Cell Block**
- **ArmorFlex® Close Cell Block**
- **ArmorFlex® Tapered Series**

**Concrete Block Classes:**
- 30s
- 50s
- 40
- 50
- 70
- 40L
- 70L
- 45s
- 55s
- 45
- 55
- 85
- 45L
- 85L

**Open/Closed Cell:**
- Open
- Closed

**Nominal Dimensions:**
- L
- W
- H

**Gross Area/Unit (sq. ft.):**
- 0.98
- 1.77
- 2.58
- 3.98
- 6.00
- 8.50

**Block Weight (lbs):**
- 31-36
- 45-52
- 62-71
- 81-94
- 120-138
- 90-106
- 173-201
- 39-45
- 53-61
- 78-89
- 94-108
- 145-167
- 108-126
- 209-243

**lbs/sq. ft.:**
- 32-37
- 45-53
- 35-41
- 67-78
- 40-45
- 54-62
- 43-50
- 67-78
- 40-45
- 54-62
- 43-50
- 82-98
- 42-49
- 81-94

**Open Area %:**
- 20
- 20
- 20
- 20
- 10
- 10
- 10
- 10
- 10
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**Notes:**
- Not to Scale
- Typical Cross Section
**A-Jacks Unit Specification**

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**ArmorWedge Unit Specification**

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<th>SYSTEM WEIGHT (LBS)</th>
<th>UNIT COVERAGE (SF)</th>
<th>COMPRESSIVE STRENGTH (PSI)</th>
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Hydraulic Analysis

Initial Project Parameters:

Channel Bottom Width = 22 ft
Depth = 1.27 ft
Slope = 0.25 ft/ft
Left Side Slope = 2 (_H:1V)
Right Side Slope = 2 (_H:1V)
Projection Height = 0 in
Bend Coefficient = 1

Project Summary:

Manning's n = 0.02 Tapered Unit
Flow = 1253.1 cfs
Depth = 1.27 ft
Velocity = 40.21 fps
Shear = 19.22 psf
Flow Area = 31.2 sq ft
Hydraulic Radius = 1.1 ft
Top Surface Width = ft
Froude No. = 6.3
Flow Type =
Unit Recommended = 70T
Factor of Safety = 1.49

Modified from Julien (1995) Analysis Date: 3/30/2010
Hydraulic Analysis

Determining n-Value:

Trapezoidal Channel: \( \frac{Q}{n} = \frac{Q}{(b + Z_L \cdot \text{depth} + Z_R \cdot \text{depth})} = 46.274 \)

Tapered Units:

If \( n < 0.02 \) then \( n = 0.02 \)

\[ n = 0.0202 \cdot \left( \frac{Q}{\text{unit}} \right)^{0.305} \cdot \left( \frac{S}{\text{depth}} \right)^{0.488} = 0.033 \]

Non-Tapered Units:

If \( n < 0.032 \) then \( n = 0.032 \)

\[ n = 0.036 \cdot \left( \frac{Q}{\text{unit}} \right)^{0.305} \cdot \left( \frac{S}{\text{depth}} \right)^{0.488} = 0.059 \]

Manning's Equation:

\[ \text{Area} = A_L + A_B + A_R \]

\[ A_L = \frac{1}{2} \cdot \text{Depth}^2 \cdot Z_L = 1.6 \quad \text{ft}^2 \]

\[ A_B = \text{Channel Bottom Width} \cdot \text{Depth} = 27.9 \quad \text{ft}^2 \]

\[ A_R = \frac{1}{2} \cdot \text{Depth}^2 \cdot Z_R = 1.6 \quad \text{ft}^2 \]

\[ \text{Area} = 31.2 \quad \text{ft}^2 \]

\[ \text{Wetted Perimeter} = P_L + P_B + P_R \]

\[ P_L = \text{Depth} \cdot (Z_L^2 + 1)^{0.5} = 2.8 \quad \text{ft} \]

\[ P_B = \text{Channel Bottom Width} = 22.0 \quad \text{ft} \]

\[ P_R = \text{Depth} \cdot (Z_R^2 + 1)^{0.5} = 2.8 \quad \text{ft} \]

\[ \text{Wetted Perimeter} = 27.7 \quad \text{ft} \]

\[ \text{Hydraulic Radius} = \frac{\text{Area}}{\text{Perimeter}} \]

\[ \text{Hydraulic Radius} = 1.1 \quad \text{ft} \]

\[ \text{Flow} = \frac{1.486}{n} \cdot \text{Area} \cdot \text{Radius}^{2/3} \cdot \text{Slope}^{1/2} = 1253.1 \quad \text{cfs} \]

- \( \text{Velocity} = \text{Flow} / \text{Area} = 40.21 \quad \text{fps} \)

- \( \text{Froude} = \text{Velocity} / (\text{Gravity} \cdot \text{Depth})^{1/2} = 6.3 \)
Hydraulic Analysis

The following illustrates the use of the factor of safety method in the selection of block sizes for ACB’s for revetment or bed armor. The following assumes that hydraulic testing has been performed for the block system to quantify a critical shear stress in the hydraulic situation. The flow depth, velocity, and site-generated shear stress were determined by the Manning’s Equation.

Given: 70T

<table>
<thead>
<tr>
<th>Unit Parameters</th>
<th>Hydraulic Parameters</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\theta_1 = 0.375$</td>
<td>$W = \text{Weight} = 128.3 \text{ lbs}$</td>
</tr>
<tr>
<td>$\theta_2 = 0.971$</td>
<td>$b = \text{Block Width} = 1.292 \text{ ft}$</td>
</tr>
<tr>
<td>$\theta_3 = 0.6$</td>
<td>$\tau_c = \text{Critical Shear} = 46.5 \text{ psf}$</td>
</tr>
<tr>
<td>$\theta_4 = 0.971$</td>
<td>$S_c = \text{Sp. Gr. of Con.} = 2.1$</td>
</tr>
</tbody>
</table>

Step 1: Compute Factor of Safety Parameters

$$\theta_1 = 26.57^\circ \quad (\text{Angle for Side Slope})$$

$$\theta_0 = 14.0^\circ \quad (\text{Angle for Bed Slope})$$

$$W_s = W \times ((S_c - 1) / S_c) = 67.2 \text{ lbs}$$

$$\tau_o = K_b \gamma y \sin (\tan^{-1} S_o) = 19.22 \text{ lbs/ft}^2$$

$$\eta_o = \tau_o / \tau_c = 0.41$$

$$a_0 = (\cos^2 \theta_1 - \sin^2 \theta_0)^{1/2} = 0.86^\circ$$

$$\theta = \arctan ((\sin \theta_0 \times \cos \theta_1) / (\sin \theta_1 \times \cos \theta_0)) = 26.6^\circ$$

$$\beta = \arctan ((\cos (\theta_0 + \theta) / ((\theta_4 / \theta_3 + 1)) * (1 - a_0^2)^{1/2} / (\eta_o * \theta_2 / \theta_1)) + \sin (\theta_0 + \theta)) = 21.83^\circ$$

$$\eta_1 = ((\theta_4 / \theta_3 + \sin (\theta_0 + \theta + \beta)) / (\theta_4 / \theta_3 + 1)) * \eta_o = 0.40$$

$$\delta = 90^\circ - \beta - \theta = 41.60^\circ$$

Step 2: Consider Effects for Specified Projection

$$F_L = F_D = 0.5 \Delta Z b p V_{des}^2 = 0.00 \text{ lbs}$$

(Lift & Drag Forces)

Step 3: Compute Factor of Safety

$${SF} = (\theta_2 / \theta_1 \times a_0) / ((1 - a_0^2)^{1/2} \times \cos \beta + \eta_1 \times (\theta_2 / \theta_1)) + (\theta_3 \times F_D \times \cos \delta + \theta_4 \times F_L) / (\theta_1 \times W_s) = 1.5$$
Hydraulic Analysis

Detailed Calculations

If H = horizontal component of side slope, then \( \theta_1 = \tan^{-1}(1/H) \)

If S = bed slope, then \( \theta_0 = \tan^{-1}(S) \)

For \( \tau_o \):

\[
\tan^{-1} S_o = 14.04 \quad \sin (\tan^{-1} S_o) = 0.243
\]

For \( a_0 \):

\[
\begin{align*}
\cos \theta_1 &= 0.894 \quad \cos^2 \theta_1 = 0.800 \\
\sin \theta_0 &= 0.243 \quad \sin^2 \theta_0 = 0.059
\end{align*}
\]

For \( \theta \):

\[
\begin{align*}
\sin \theta_0 \cos \theta_1 &= 0.217 & (\sin \theta_0 \cos \theta_1) / (\sin \theta_1 \cos \theta_0) = 0.500 \\
\sin \theta_1 &= 0.447 \\
\cos \theta_0 &= 0.970 \\
\sin \theta_1 \cos \theta_0 &= 0.434
\end{align*}
\]

For \( \beta \):

\[
\begin{align*}
\cos (\theta_0 + \theta) &= 0.759 & (\varphi_4 / \varphi_3 +1) * (1 - a_0^2)^{1/2} / (\eta_1 \varphi_2 / \varphi_3) = 1.245 \\
\varphi_4 / \varphi_3 +1 &= 2.618 & (\varphi_4 / \varphi_3 +1) * (1 - a_0^2)^{1/2} / (\eta_1 \varphi_2 / \varphi_3) + \sin (\theta_0 + \theta) = 1.895 \\
(1 - a_0^2)^{1/2} &= 0.509 & \cos (\theta_0 + \theta) / ((\varphi_4 / \varphi_3 +1) * (1 - a_0^2)^{1/2} / (\eta_1 \varphi_2 / \varphi_3) + \sin (\theta_0 + \theta)) = 0.401 \\
\eta_1 \varphi_2 / \varphi_3 &= 1.070 \\
\sin (\theta_0 + \theta) &= 0.651
\end{align*}
\]

For \( \eta_1 \):

\[
\begin{align*}
\varphi_4 / \varphi_3 &= 1.618 & \varphi_4 / \varphi_3 + \sin (\theta_0 + \theta + \beta) = 2.505 \\
\sin (\theta_0 + \theta + \beta) &= 0.886 & (\varphi_4 / \varphi_3 + \sin (\theta_0 + \theta + \beta)) / (\varphi_4 / \varphi_3 +1) = 0.957 \\
\varphi_4 / \varphi_3 +1 &= 2.618 \\
\eta_1 &= 0.413
\end{align*}
\]

For \( F_L = F_D \):

\[
\rho = 1.940 \text{ slugs/ft}^3
\]

For SF:

\[
\begin{align*}
\varphi_3 / \varphi_1 * a_0 &= 2.229 & (\varphi_3 * F_D * \cos \delta + \varphi_4 * F_L) / (\varphi_1 * W_s) = 0.000 \\
(1 - a_0^2)^{1/2} * \cos \beta &= 0.472 & (1 - a_0^2)^{1/2} * \cos \beta + \eta_1 * (\varphi_3 / \varphi_4) + (\varphi_3 * F_D * \cos \delta + \varphi_4 * F_L) / (\varphi_1 * W_s) = 1.496 \\
\eta_1 * (\varphi_3 / \varphi_4) &= 1.024 \\
\cos \delta &= 0.748 \\
\varphi_3 * F_D * \cos \delta + \varphi_4 * F_L &= 0.000 \\
\varphi_1 * W_s &= 25.200
\end{align*}
\]

Modified from Julien (1995)  
Analysis Date: 3/30/2010
## Parameters for Factor of Safety Calculations

<table>
<thead>
<tr>
<th>Block Class</th>
<th>Submerged Weight (lbs)</th>
<th>$\theta_1$ (ft)</th>
<th>$\theta_2$ (ft)</th>
<th>$\theta_3$ (ft)</th>
<th>$\theta_4$ (ft)</th>
<th>$\tau_c$ (psf)</th>
<th>Width (ft)</th>
<th>Weight (lbs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>40T</td>
<td>35.500</td>
<td>0.198</td>
<td>0.971</td>
<td>0.317</td>
<td>0.971</td>
<td>31.800</td>
<td>1.292</td>
<td>67.773</td>
</tr>
<tr>
<td>50T</td>
<td>44.800</td>
<td>0.250</td>
<td>0.971</td>
<td>0.400</td>
<td>0.971</td>
<td>36.900</td>
<td>1.292</td>
<td>85.527</td>
</tr>
<tr>
<td>60T</td>
<td>56.000</td>
<td>0.313</td>
<td>0.971</td>
<td>0.500</td>
<td>0.971</td>
<td>42.100</td>
<td>1.292</td>
<td>106.909</td>
</tr>
<tr>
<td>70T</td>
<td>67.200</td>
<td>0.375</td>
<td>0.971</td>
<td>0.600</td>
<td>0.971</td>
<td>46.500</td>
<td>1.292</td>
<td>128.291</td>
</tr>
</tbody>
</table>

Modified from Julien (1995)  
Analysis Date: 3/30/2010
LOW PROFILE ARC SHAPE: 99A24-24

\[ Q_{\text{out},\text{channel}} = 4899 \text{ cfs} \quad A_{\text{channel}} = 377.6 \text{ ft}^2 \quad \frac{V^2}{2g} = 168.3259 = 2.62 \quad y_c = 7.28 \]

\[ l_{\text{culvert}} = 130 \text{ ft} \quad \text{Slope} = 0.03 \text{ ft/ft} \quad \text{(S)} \quad E_c = 9.90 \quad \text{minimum specific energy} \]

\[ \text{Culvert span} = 27.08 \text{ ft} \quad \text{Culvert rise} = 16.42 \text{ ft} \quad \text{Culvert Area} = 412 \text{ ft}^2 \]

Assuming inlet control submerged and orifice flow, the governing hydraulic equation is the orifice-flow equation given as:

\[ Q = C_d A_o \sqrt{2g(HW)} \]

Where:
- \( Q \) = flow discharge
- \( C_d \) = coefficient of discharge
- \( A_o \) = Cross-sectional area of inlet
- \( HW \) = head on the inlet invert of the culvert

Checking for inlet submerge:

\[ \frac{Q}{Ad^{0.5}} = 2.93 < 4 \quad \text{Thus unsubmerged culvert equation should be used:} \]

\[ \frac{HW}{d} = E_c + K \left( \frac{Q}{Ad^{0.5}} \right)^M - 0.5S \]

where:
- \( K, M \) = Constants for different types of inlets.

For a arc culvert mitered to slope:

\[ K = 0.03 \quad M = 1 \]

\[ HW = 11.09 \text{ ft} < 16 \text{ o.k.} \]

Checking outlet: \( n = 0.024 \) corrugated storm drain

Downstream trapezoidal channel:
- Bottom width = 30 ft
- Side slopes 3H:1V
- Slope =
TAILWATER CALCULATION:

\[ Q = 4899 \text{ cfs} \]
\[ n = 0.035 \text{ Excavated channel-smooth and uniform rock cuts (normal)} \]

\[ A = \frac{Q \cdot n}{1.49 \cdot R^{\frac{5}{3}} \cdot S^{\frac{1}{3}}} = y(b + my) \]

\[ R = \frac{A}{P} = \frac{y(b + my)}{b + 2y(1 + m^2)^{\frac{1}{2}}} \]

Critical depth \( y_c = 7.28 \text{ ft} \)
Flow velocity: \( V = 12.84 \text{ ft/s} \)

\[ TW = \frac{(y_c + d)}{2} = 11.85 \text{ ft} \]

Culvert dimensions

\[ \text{TW} = \frac{(y_c + d)}{2} = 11.85 \text{ ft} \]

Substituting the previous value in the tailwater equation:

\[ HW = TW - S_d L + (1 + K_e + f \frac{L}{4R}) \frac{Q^2}{2gA^2} \]

Where: \( Ke = \text{entrance loss coefficient}= 0.7 \text{ for an arch, corrugated metal mitered t conform fill slope} \)
\( F = \text{Darcy-Weisbach friction factor} \)
\( R = \text{full flow hydraulic radius} \)
\( A = \text{culvert cross section} \)

HW = 10.80 ft < 11.09 ft (inlet control head)
SUPER-SPAN™ and SUPER-PLATE®

Over 4000 SUPER-SPANS in Place

Since 1967, more than 4,000 structures have been built on five continents. That makes SUPER-SPAN the most widely accepted, long-span, corrugated steel design in the world.

SUPER-SPAN structures with individual spans up to 50 feet are serving as bridges, railroad overpasses, stream enclosures, vehicular tunnels, culverts, and conveyor conduits. Installations have involved almost every job condition possible, including severe weather and unusual construction time constraints.

National specification

SUPER-SPAN's popularity has resulted in a national specification written for long-span, corrugated metal structures by the American Association of State Highway and Transportation Officials. A.A.S.H.T.O. Standard Specifications (Section 12.7) for Highway Bridges provide for the selection of acceptable combinations of plate thickness, minimum cover requirements, plate radius and other design factors. Material is covered by A.A.S.H.T.O. M 167 AND ASTM A 761. Installation is covered by A.A.S.H.T.O. standard specification for highway bridges (Sec. 12) and ASTM A 761.

Acceptance

Many state and federal agencies recognize the excellent performance and economy of SUPER-SPAN corrugated structures. In a 1979 memorandum, the chief of FHWA's Bridge Division noted that in the previous 15 years, several hundred CONTECH SUPER-SPAN Culverts had been erected in the United States and Canada and their performance had been excellent.

In a 1983 report to the Secretary of Transportation, the General Accounting Office stated, "Some innovations, such as using certain long-span culverts rather than building conventional bridges, have substantially lowered bridge costs."

Aluminum Long-Span structures (SUPER-PLATE)

SUPER-PLATE structures add both longitudinal stiffeners (thrust beams) and circumferential stiffeners (reinforcing ribs) to conventional Aluminum Structural Plate to achieve larger sizes. Clear spans in excess of 30 feet and clear areas over 435 square feet are achievable with SUPER-PLATE. Available shapes include low-profile and high-profile arch and horizontal ellipse. Consult a CONTECH representative for additional information.

High-profile arch SUPER-SPAN (43' 3" span, 27' rise) in Hamilton, Ohio to span a wetland and to provide a wildlife crossing.
General design and installation characteristics

As conventional round structures increase in diameter beyond 16-18 feet, they become more difficult to install. It becomes increasingly difficult to both control the shape and to achieve good backfill support. CONTECH’s SUPER-SPAN and SUPER-PLATE help overcome these problems through the use of both special shapes and concrete thrust beams.

SUPER-SPAN/SUPER-PLATE solves the problem

The horizontal ellipse, low-profile and high-profile arch shapes are wide-span, reduced-rise structures. They provide large open areas with less rise than comparable circular shapes. Sidewalls are compact with a modest radius to provide a more rigid pipe wall to compact against. At the same time, the large radius top arc of these structures is flatter and, therefore, has less tendency to peak as it supports the sides (see Figure 9).

![Figure 9](image)

By contrast, pear and pear-arch shapes provide relatively high-rise structures. These shapes orient their sides at the derivable angle to the soil pressures (see Figure 10). Their smaller radius crowns are typically heavy gauge to provide the necessary restraint at the top.

![Figure 10](image)

The thrust beam is the key element to SUPER-SPAN and SUPER-PLATE success. Besides providing perfect backfill in the important area above the spring line, it acts as a floating footing for the critical large radius top arch of the structure. It fixes the end of the arch, stiffening it and reducing deflection as backfill goes over the top.

![Thrust Beam Function](image)

With the shape on the left, it is difficult to obtain adequate compaction of the backfill at the critical 3/4 rise point.

Compare it to the SUPER-SPAN on the right. Excellent compaction* and a high restraining force (R) is readily obtained against the vertical surface of the thrust beam. Force (R) acts on the vertical surface to prevent significant horizontal movement on the pipe wall at the 3/4 rise point under dead and live loads.

*See Backfilling and Backfill material on Design Details on page 81.

The thrust beam also provides a solid vertical surface that is easy to backfill against to obtain excellent compaction*. After installation, the beam effectively controls possible horizontal spreading of the top arch.

SUPER-SPAN and SUPER-PLATE structures, by means of their shape and thrust beams (which reduce the central angle of the effective top arch to 80 degrees) have added stability against deflection and snap-through buckling. They can be economically designed and installed within recognized AASHTO/AISI critical stresses and seam strength limits.

Horizontal reinforcement bars are tied to CONTECH bent and threaded rods to provide reinforcement for the concrete thrust beam.
## Structural design

### Table 53  
Minimum Thickness — Minimum Cover Table, Ft. H-20, HS-20, H-25, HS-25 Live Load

<table>
<thead>
<tr>
<th>Top Radius R, Ft.</th>
<th>0.111&quot; (12)</th>
<th>0.138&quot; (10)</th>
<th>0.168&quot; or 0.188&quot; (8 or 7)</th>
<th>0.218&quot; (3)</th>
<th>0.249&quot; (3)</th>
<th>0.280&quot; (1)</th>
</tr>
</thead>
<tbody>
<tr>
<td>15'</td>
<td>2.5'</td>
<td>2.5'</td>
<td>2.5'</td>
<td>2.0'</td>
<td>2.0'</td>
<td>2.0'</td>
</tr>
<tr>
<td>15'-17'</td>
<td></td>
<td>3.0'</td>
<td>2.5'</td>
<td>2.0'</td>
<td>2.0'</td>
<td>2.0'</td>
</tr>
<tr>
<td>17'-20'</td>
<td></td>
<td>3.0'</td>
<td>2.5'</td>
<td>2.5'</td>
<td>2.5'</td>
<td>2.5'</td>
</tr>
<tr>
<td>20'-23'</td>
<td></td>
<td>3.0'</td>
<td>3.0'</td>
<td>3.0'</td>
<td>3.0'</td>
<td>3.0'</td>
</tr>
<tr>
<td>23'-25'</td>
<td></td>
<td></td>
<td>4.0'</td>
<td>4.0'</td>
<td>4.0'</td>
<td>4.0'</td>
</tr>
</tbody>
</table>

### Notes
1. Designs listed are for steel 6" x 2" corrugation only. For aluminum 5" x 2 1/2" corrugation design, please contact your local CONTECH representative.
2. Heights of cover for highway live loads given are to top of concrete pavement or bottom of flexible pavement.
3. Minimum covers for E 80 live loads are approximately twice those for HS 20. However, E 80 minimums must be established for individual applications.
4. Minimum covers for construction loads and similar heavy wheel loads must be established for individual applications.
5. The table assumes a granular backfill over the crown of the structure to the full minimum cover depth (height) compacted to not less than 90 percent AASHTO T180 density.
6. Call a CONTECH representative for Peer shape gauges.

A SUPER-SPAN or SUPER-PLATE structure is essentially an engineering combination of steel and soil. Maximum fill heights are calculated on the basis of A.A.S.H.T.O./AISI design methods using top radius to calculate ring compression (thrust=pressure x R,) with allowable wall stress of 16,500 psi. In the design method, AISI requires a seam strength safety factor of two, while A.A.S.H.T.O. requires a seam strength safety factor of three.

In accordance with A.A.S.H.T.O., buckling and flexibility factors are not calculated. These factors are covered by the minimum thickness/minimum cover table on this page and special geometry limitations spelled out by A.A.S.H.T.O.

### Shallow fill

Minimum designs are shown in Table 53. Ordinarily, shallow cover structures will be at the minimum [shown in the tables] thickness required for installation and to prevent against buckling. Wall stresses can be checked in deep cover applications by adding the soil load to the appropriate live load.

When adding the total live load over the structure, it is necessary to distribute it over an appropriate area of the structure which varies with the fill height.

### Special designs

Structure sizes shown in Tables 55 through 61 are standard shapes. Intermediate or larger sizes are available. These special sizes also are designed in accordance with the A.A.S.H.T.O. design method.

Minimum covers shown in Table 53 are based on standard construction. Somewhat lower covers are possible with special measures such as using concrete relieving slabs. Special designs are also available for fill heights exceeding the normal limitations of standard structures. Your CONTECH representative can provide information on special requirements.

### Foundation

The foundation under the structure and sidefill zones must be evaluated by the design engineer to ensure adequate bearing capacity. Differential settlement between the structure and sidefill must be minimal.

### Hydraulic design

The most commonly used SUPER-SPAN and SUPER-PLATE hydraulic shapes are the horizontal ellipse, the low-profile arch, and the high-profile arch. Hydraulic data for these shapes are presented in tabular and graphical form in the current edition of the Handbook of Steel Drainage and Highway Construction Products. Standard procedures are presented in the Hydraulics chapter of the handbook to determine the headwater depth required for a given flow through these structures under both inlet and outlet control conditions.

In addition, the hydraulic design series of publications from FHWA offers guidance regarding hydraulic capacity of these structures.

### Installation precautions

During the installation and prior to the construction of permanent erosion control and end-treatment protection, special precautions may be necessary. The structure must be protected from unbalanced loads and from any structural loads or hydraulic forces that might bend or distort the unsupported ends of the structure. Erosion wash out of previously placed soil support must be prevented to ensure that the structure maintains its load capacity.
CONTECH SUPER-SPAN structures have proven both practical and economical to construct in a wide range of applications and conditions. Nevertheless, there are basic rules of installation that must be obeyed to ensure acceptable performance.

Comprehensive installation and inspection standards are furnished with every SUPER-SPAN purchase. These documents should be studied thoroughly by the contractor and engineer. The following material highlights the key elements involved in the proper construction of a CONTECH SUPER-SPAN.

Excavation, foundation and bedding

There must be adequate distance between the SUPER-SPAN and questionable native soils. Bedding must be pre-shaped for structures with inverted, A loose soil cushion should be provided for the bottom plates. Base channels for arches must be square to the centerline on arch structures.

Erection

Plates can be placed either one at a time or in preassembled units of two or more plates in a ring.

All bolts in a newly hung plate or assembly should be tightened before adding the next unit above it. This should be done only with the plates in proper relation to each other for correct curvature and alignment in the structure. It may be necessary to use cables, props, or jigs to keep the plates in position during tightening.

The structure cross-section must be checked regularly during assembly. Its shape must be symmetrical, with the plates forming smooth, continuous curves. Longitudinal seams should be tight and plate ends should be parallel to each other.

Backfilling

SUPER-SPANs are flexible structures, therefore care is required during the placement and compaction of backfill. An effective system to monitor the structure during the backfilling process must be established.

Select an approved structure backfill material for the zone around the SUPER-SPAN. Establish soil density curves and determine proper frequencies and procedures for testing. The equipment used to place and compact fill around and over the structure should be selected based on the quality of the backfill and the shape of the SUPER-SPAN. Such plans should be verified in the initial backfilling stages.

Use only backfilling methods and equipment that obtain specified density without excessive movement or deformation of the structure.

Backfill material

CONTECH's specification for backfill material contains the following as listed in the A.A.S.H.T.O. Bridge Specification:

1. Granular type soils shall be used as structure backfill (the envelope next to the metal structure). Well-graded sand and gravel that is sharp, rough, and angular is preferred. Approved stabilized soil shall be used only under direct supervision of a competent, experienced soils engineer. Plastic or cohesive soils should not be used.

2. The structure backfill material shall conform to one of the following soil classifications from A.A.S.H.T.O. Specification M145, Table 2; for height of fill less than 12 feet, A-1, A-2-4 and A-2-5; for height of fill of 12 feet and more and all pear or pear-arch structures, A-1. Structure backfill shall be placed and compacted to not less than 90 percent density, per A.A.S.H.T.O. T 180.

3. The extent of the select structural backfill outside the maximum span is dependent on the quality of the adjacent embankment, loading and shape of the structure. It may be necessary to excavate native soil at the sides to provide an adequate width needed for compaction. For ordinary installations with a good quality, well-compacted embankment or in situ soil adjacent to the structure backfill, a minimum width of structural backfill six feet beyond the structure is usually required. The engineer must evaluate the in situ conditions to ensure adequate bearing capacity. The structure backfill shall extend to the minimum cover elevation (Table 53—page 80) above the structure.

Monitoring Backfill

Regular monitoring is required during backfilling to assure a structure with a proper shape and that compaction levels are achieved. A CONTECH technician will confirm the structure's shape before backfilling, then monitor the shape and verify compaction readings until the backfill reaches the minimum cover level.

Special requirements

Very large or high structures sometimes call for additional special provisions for shape control during backfilling.

The minimum stiffness requirements for some structures shown in Table 53 on Page 80 may need to be augmented by increased design stiffness or mandatory top loading. Top loading requires the placement of a modest blanket of soil on the crown when backfill is approximately at the springline height.
### Table 57. TYPICAL HIGH PROFILE ARCH SHAPES

(All Dimensions to Inside Crests)

<table>
<thead>
<tr>
<th>Structure Number</th>
<th>Maximum Span</th>
<th>Bottom Span</th>
<th>Total Rise</th>
<th>Top Rise</th>
<th>Top Radius</th>
<th>Upper Side Radius ( R_u )</th>
<th>Lower Side Radius ( R_l )</th>
<th>Angle Below Horizontal ( A )</th>
<th>Approx. Area (Sq. Ft.)</th>
<th>Shape Factor ( R_u/R_l )</th>
</tr>
</thead>
<tbody>
<tr>
<td>69A15-9</td>
<td>20'-1&quot;</td>
<td>19'-7&quot;</td>
<td>9'-1&quot;</td>
<td>6'-6&quot;</td>
<td>13'-1&quot;</td>
<td>4'-6&quot;</td>
<td>13'-1&quot;</td>
<td>11'-18&quot;</td>
<td>152</td>
<td>2.91</td>
</tr>
<tr>
<td>69A18-18</td>
<td>20'-8&quot;</td>
<td>18'-10&quot;</td>
<td>12'-1&quot;</td>
<td>7'-3&quot;</td>
<td>13'-1&quot;</td>
<td>5'-5&quot;</td>
<td>13'-1&quot;</td>
<td>21'-44&quot;</td>
<td>214</td>
<td>2.40</td>
</tr>
<tr>
<td>75A15-18</td>
<td>21'-6&quot;</td>
<td>19'-10&quot;</td>
<td>11'-8&quot;</td>
<td>6'-9&quot;</td>
<td>14'-3&quot;</td>
<td>4'-6&quot;</td>
<td>14'-3&quot;</td>
<td>19'-13&quot;</td>
<td>224</td>
<td>3.13</td>
</tr>
<tr>
<td>75A21-24</td>
<td>22'-10&quot;</td>
<td>19'-10&quot;</td>
<td>14'-6&quot;</td>
<td>8'-2&quot;</td>
<td>14'-3&quot;</td>
<td>6'-4&quot;</td>
<td>14'-3&quot;</td>
<td>26'-24&quot;</td>
<td>284</td>
<td>2.24</td>
</tr>
<tr>
<td>78A15-18</td>
<td>22'-3&quot;</td>
<td>20'-7&quot;</td>
<td>11'-10&quot;</td>
<td>6'-11&quot;</td>
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**Note:** Other sizes are available for special designs.

![End View - High Profile Arch](image-url)