Perform a preliminary design for a bridge on a state highway over a large creek in rural Alabama. Produce a construction layout drawing showing profile and plan views of the bridge and approach embankments.

**Traffic Information.** This information is used to calculate the number of lanes and the bridge width. These calculations are frequently performed by a transportation engineer.

Rural location, flat terrain

ADT = 5000 veh/day (2-way)

% trucks = 5% (reasonable for rural area; I20/59 has 30% trucks, one of the highest in the state, for comparison)

Functional Class of highway = major collector growth rate = 3%

**Hydraulic Information.** This information is used to calculate the minimum required waterway opening (in square feet).

design flood = 50-year flood (this is a state route; 25-yr flood may be used for small county roads)

Q_50 (flow rate for 50-yr flood) = 25,000 cfs

WSE_50 (water surface elevation for 50-yr flood) = 245 ft

Streambed is coarse sand

**Stream Profile** This information is from a survey along the road/bridge centerline.

<table>
<thead>
<tr>
<th>Station</th>
<th>Elevation</th>
</tr>
</thead>
<tbody>
<tr>
<td>0+00</td>
<td>250</td>
</tr>
<tr>
<td>4+00</td>
<td>240</td>
</tr>
<tr>
<td>6+00</td>
<td>230</td>
</tr>
<tr>
<td>7+00</td>
<td>210</td>
</tr>
<tr>
<td>8+00</td>
<td>230</td>
</tr>
<tr>
<td>10+00</td>
<td>240</td>
</tr>
<tr>
<td>14+00</td>
<td>250</td>
</tr>
</tbody>
</table>

Design Requirements:

Design for Level of Service (LOS) “C”. No barge traffic on waterway.
1. Determine Bridge Width

ADT 4,000 veh/day average daily traffic

% trucks 5%

$E_T = 1.5$ equivalent cars per truck (1.7, 4 and 8 for freeways)

use 1.5 for level terrain
3.0 for rolling terrain
6.0 for Mountainous terrain

ADT adjusted for truck traffic $= ADT \times (1 - \%_{\text{trucks}} + \%_{\text{trucks}} \times E_T) \approx 5,125$

growth rate 3% typically varies between 1% and 5%, depending on local economy, etc.

design year 20yrs into the future

ADT in 20 years $= ADT \times (1 + \text{growth\_rate})^{20} \approx 9,256$ veh/day, 2 way

peak volume factor (PVF) = 0.15
  rural: 0.12 to 0.18
  suburban: 0.10 to 0.15
  urban: 0.08 to 0.12

Design Hourly Volume (DHV) $= ADT \times \text{peak\_volume\_factor} \approx 1,111$ vh/hr, 2 way

Desired LOS C Desired Level of Service ("C" is typical)

For LOS "C", Allowable DHV = 1200 vh/hr for two lanes, 2-way traffic
(see LOS Characteristics handout)

Therefore, Use 2 traffic lanes

Lane Width = 12ft

Shoulder Width = 8 ft

Min. Bridge Width $= 2 \times 12ft + 2 \times 8ft + 2 \times 1.3$ ft (Jersey barrier rail) $= 42.6$ ft

ALDOT has 44ft wide standard design

shoulder width $= 44ft - 24ft - 2.6ft) / 2 = 8.7$ ft

Use 44 ft wide bridge, out-to-out
2. Calculate Bridge “Low-Steel” Elevation

low steel = lowest part of superstructure

elevation of low steel must be

   > 16ft above “under”-road for grade separations (17ft is better)
   > 2ft above WSE_50 for stream crossings
   > navigation requirement for rivers with barge traffic (set by Coast Guard)

Elevation of low steel = 245ft + 2 ft ,  \[ \text{Elevation of low steel} = 247 \text{ ft} \]

3. Calculate Min. Waterway Opening (A_50_min)

\[ V_{\text{max}} = 4 \text{ pfs for a streambed of course sand (see table below)} \]

\[ A_{50 \_\text{min}} = \frac{Q_{50}}{V_{\text{max}}} = \frac{25,000 \text{ cfs}}{4 \text{ fps}} \]

\[ A_{50 \_\text{min}} = 6,250 \text{ sf} \]

\( V_{\text{max}} \) is usually specified by someone knowledgeable in bridge hydraulics and scour. In Alabama, an ALDOT hydrologist usually visits the site and supplies \( V_{\text{max}} \). Typical values from the Army Corps of Engineers for various soil types are shown below.

<table>
<thead>
<tr>
<th>Streambed Material</th>
<th>Max. Permissible Velocity, fps</th>
</tr>
</thead>
<tbody>
<tr>
<td>fine sand</td>
<td>2</td>
</tr>
<tr>
<td>coarse sand</td>
<td>4</td>
</tr>
<tr>
<td>fine gravel</td>
<td>6</td>
</tr>
<tr>
<td>sandy silt</td>
<td>2</td>
</tr>
<tr>
<td>silty clay</td>
<td>3.5</td>
</tr>
<tr>
<td>clay</td>
<td>6</td>
</tr>
<tr>
<td>soft shale</td>
<td>3.5</td>
</tr>
<tr>
<td>soft sandstone</td>
<td>8</td>
</tr>
<tr>
<td>other sedimentary</td>
<td>10</td>
</tr>
<tr>
<td>hard rock (igneous or hard metamorphic)</td>
<td>20</td>
</tr>
</tbody>
</table>

From hand-drawn sketch of stream cross-section, \[ A_{50 \_\text{natural}} \sim 9,900 \text{ sf}, \text{ OK} \]

(from AutoCAD drawing, A_50_nat = 10,000 sf)
4. Locate Abutments (CL of bearings)

Use 2:1 foreslope (in the longitudinal direction at the abutments)

Try #1:

Try Abutment 1 bearing at Sta 5+00, Elev 247 (low steel elevation) And Abutment 2 at Sta 9+00, Elev 247,

From hand-drawn drawing: \( A_{50\_prov’d} \approx 6800 \text{ sf} \)

From geometry using equation below: \( A_{50\_prov’d} = 7,190 \text{ sf} \)

Area of a closed shape = \( \frac{1}{2} \sum_{i=1}^{n} (x_i y_{i+1} - x_{i+1} y_i) \), where point “n” is the same as point “1”.

\( A_{50\_prov’d} = 7,190 \text{ sf} > 6,250 \text{ sf} = A_{50\_min}, \text{ OK} \)

Try #2: try moving abutments closer to minimize cost of bridge

Abut. 1 at Sta 5+50, Abut. 2 at Sta 8+50, \( A_{50\_prov’d} = 5,490 \text{ sf}, \text{ NG} \)

Use Try #1 \( A_{50\_prov’d} = 7237 \text{ sf} \)

5. Select Superstructure Type & Pier Locations

400-ft-long bridge

Try spans of 130’, 140’, 130’, all BT-72 (see ALDOT Estimated Bridge Costs Sheet)

<table>
<thead>
<tr>
<th>Station</th>
<th>Elevation (top of bearing)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abut 1</td>
<td>5+00</td>
</tr>
<tr>
<td>Pier 2</td>
<td>6+30</td>
</tr>
<tr>
<td>Pier 3</td>
<td>7+70</td>
</tr>
<tr>
<td>Abut 2</td>
<td>9+00</td>
</tr>
</tbody>
</table>

Superstructure Depth = 6’ Girder depth for BT-72 (ALDOT cost sheet)

Assume buildup + slab = 1’ thick

Therefore road surface elevation = 245’ + 2’ + 6’ + 1’

Road Surface Elev = 254’
6. Estimate Construction Cost of Bridge & Embankments

**Bridge Cost:**

Deck Area = 400ft x 44ft = 17,600 sf

Superstructure Type = Precast Concrete Girders, BT72

Max. Pier Ht = 23 ft (from sketch)

Cost/sf = $65/sf for BT72 with pier ht between 40’ to 60’ (AIDOT Estimated Bridge Cost Sheet)

Note: Our max. pier height = 22’ which is less than 40’ – 60’ typically used for BT72 girders. Should consider using more spans with shorter girders (e.g AASHTO Type III, max span = 80’)

Assume construction costs have increased at the rate of inflation

Using data from the internet, average inflation rate between 2000 and 2012 = 2.7%

Bridge Cost = 17,600sf x $65/sf x (1.027)\(^{12}\)  

**Estimated Bridge Cost = $1,575,000**

**Cost of Approach Embankments:**

ADT in Year 2032 = 9,300 veh/day

Terrain = flat

From Typical Cross Section handout:

- use 3:1 fill slope from Sta 0+00 to Sta 4+00
- use 2:1 fill slope at abutment
  (use linear transition from 3:1 to 2:1 slopes between Sta 4+00 and Abut.)

Intersection of ground and top of embankment (Elev 254 ft) is at Sta -160.

**Calculate side slope volumes** for each of two sections:

<table>
<thead>
<tr>
<th></th>
<th>Section 1</th>
<th>Section 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>h</td>
<td>0</td>
<td>14</td>
</tr>
<tr>
<td>h</td>
<td>14</td>
<td>19</td>
</tr>
<tr>
<td>b</td>
<td>0</td>
<td>42</td>
</tr>
<tr>
<td>b</td>
<td>42</td>
<td>38</td>
</tr>
<tr>
<td>L</td>
<td>560</td>
<td>100</td>
</tr>
<tr>
<td>V</td>
<td>54,880</td>
<td>32,920</td>
</tr>
</tbody>
</table>

\[ V_{side\_slope} = 87,800 \text{ cf} \]

For 2 sides of embankment, \( V_{sides} = 175,600 \text{ cf} \)
Volume beneath road:

\[
\text{road}\_\text{width} = 40 \text{ ft} \quad (= 2 \times (12' \text{ lane} + 8' \text{ shoulder})
\]

<table>
<thead>
<tr>
<th>Section 1</th>
<th>Section 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>V_road_section</td>
<td>156,800</td>
</tr>
</tbody>
</table>

\[\text{V\_road} \quad 222,800 \text{ cf}\]

Volume in front of abutment:

\[
\text{h\_fill\_at\ centerline\ bearing} = 12 \text{ ft}
\]
\[\text{Sta at toe of front slope} = 526.7 \text{ ft}\]
\[\text{Length of front fill} = 526.7 \text{ ft} - 500 \text{ ft} = 26.7 \text{ ft}\]

\[\text{V\_front\_slope} \quad 7,000 \text{ cf}\]

Volume at corners:

(between side slope and fore slope)

Assume triangular base of width 19 ft x 2 and length 12 ft x 2 and height 19 ft

\[\text{V\_corner} = 2900 \text{ cf}\]

\[\text{V\_2\_corners} = 5,800 \text{ cf}\]

Total Embankment Fill:

\[\text{Total Embankment Fill} = 411,200 \text{ cf}\]

\[\text{Volume Fill for Left Embankment} = 15,200 \text{ cy}\]

Construction Cost of Embankments:

Assume $7/cy for embankment fill (in 2012 dollars). Also assume the right-side embankment is the same volume (due to symmetry).

\[\text{Cost of embankments} = 7/cy \times 15,200 \text{ cy/embankment} \times 2 \text{ embankments}\]

\[\text{Cost of Embankments} = 213,000\]

Total Cost of bridge + approach embankments = $1,575,000 + $213,000

\[\text{Total Estimated Cost of bridge + approach embankments} = 1,800,000\]