Stream Restoration Design Steps

1. Determine Restoration Need and Approach

a. Visit site and assess stream existing condition and evaluate opportunities and constraints
   i. Evaluate stability and condition
   ii. Evaluate channel evolution stage
   iii. Evaluate channel substrate
   iv. Identify existing bankfull features, survey riffle cross-sections, check regional curve
   v. Collect detailed site, morphology and topographic data (provided)

b. Meet with client (City of Raleigh) and collect neighborhood perceptions, preferences

c. Watershed assessment (USGS StreamStats http://water.usgs.gov/osw/streamstats/)
   i. Delineate watershed
   ii. Identify current and future landuse
   iii. Evaluate hydrology (2,5,10, 50 and 100-year storm Q)

d. Identify restoration goals and objectives (City, residents, ecological uplift potential)

e. Select appropriate restoration options (Priority 1, 2, 3, RSC or other)

f. Identify sources for design criteria
   i. Reference reaches
   ii. Past projects (e.g. visit nearby restoration projects)
   iii. Design guidance documents

2. Select a Target Stream Type, Sinuosity and Slope

a. Determine valley slope from topographic map, s_{val}, by measuring the elevation change, $\Delta Elev$, and the length of the valley (L_{val}), where $s_{val} = \frac{\Delta Elev}{L_{val}}$

b. Select a target sinuosity, K, based on desired stream type and reference reach

c. Calculate proposed average stream slope, $s = \frac{s_{val}}{K}$

3. Develop Proposed Cross-Sections – Riffle & Pool

a. Review reference reach dimension data provided

b. Select riffle bankfull cross-sectional area, A_{bkf}, using existing condition cross-sections surveyed at riffles

c. Compare with regional curves

d. Select width-to-depth ratio, $\left[\frac{W_{bkf}}{d_{bkf}}\right]$

e. Calculate riffle bankfull width, $W_{bkf} = \sqrt{A_{bkf}\ x\ \left[\frac{W_{bkf}}{d_{bkf}}\right]}$

f. Calculate riffle mean depth, $d_{bkf} = \frac{A_{bkf}}{W_{bkf}}$

g. Calculate Discharge and Velocity

   i. Estimate Manning's channel roughness value, n

   ii. Estimate hydraulic radius, $R = \frac{A_{bkf}}{Wetted\ Perimeter(WP)}$; where WP can be approximated by: $WP = W_{bkf} + 2\ x\ d_{bkf}$

   iii. Calculate Bankfull Discharge, Q_{bkf}, using Manning's Equation and compare to regional curves, $Q_{bkf} = \frac{1.49}{n} A_{bkf}\ R^{\frac{2}{3}}\ s^{\frac{1}{2}}$

   iv. Calculate Bankfull velocity, $v_{bkf} = \frac{Q_{bkf}}{A_{bkf}}$; evaluate relative to channel erosion potential

h. Check sediment transport competency: Calculate Shear Stress, $= \lambda Rs$, and determine the predicted particle size entrained using Shield's Diagram. If larger than the D_{100}, increase $\left[\frac{W_{bkf}}{d_{bkf}}\right]$ and/or reduce channel slope.

i. Calculate riffle max depth, $d_{mbkf} = d_{bkf}\ x\ \left[\frac{d_{mbkf}}{d_{bkf}}\right]$

j. Determine entrenchment ratio, ER. Measure the width of the flood-prone area, W_{fpa}, at an elevation of twice the maximum bankfull depth, where $ER = \frac{W_{fpa}}{W_{bkf}}$

k. Calculate pool area, $Apool = \left[\frac{Apool}{Abkf}\right] x\ Abkf$

l. Calculate pool width, $Wpool = \left[\frac{Wpool}{Wbkf}\right] x\ Wbkf$

m. Calculate pool max depth, $d_{pool} = d_{bkf}\ x\ \left[\frac{d_{pool}}{d_{bkf}}\right]$

n. Draw typical riffle & pool cross-sections using provided excel spreadsheet

4. Develop Proposed Channel Alignment

a. Review reference reach pattern data provided

b. Calculate a range and average for meander-wavelength, $L_m = W_{bkf}\ x\ \left[\frac{L_m}{W_{bkf}}\right]$

c. Calculate a range and average for belt width, $W_{blt} = W_{bkf}\ x\ \left[\frac{W_{blt}}{W_{bkf}}\right]$

d. Calculate a range and average for radius of curvature, , $R_c = W_{bkf}\ x\ \left[\frac{R_c}{W_{bkf}}\right]$

e. Select a target sinuosity based on desired stream type and reference stream(s), K

f. Calculate pool-to-pool spacing, $p - p = \left[\frac{p-p}{W_{bkf}}\right] \times W_{bkf}$

g. Draw a new proposed plan view layout for stream using R_c, L_m, W_{blt}, p-p and values *(Step 18)*
h. Delineate the thalweg and measure the stream length along the thalweg in the new channel.
i. Calculate resulting sinuosity, $K = L_{stream} / L_{val}$.
j. Calculate the Average Slope, $S = \frac{S_{val}}{K}$
k. Compare resulting s and K to target values. If different, check the layout for possible adjustments. If a significant difference remains, return to step 2 & 3 as adjustment to slope and width to depth ratio may be necessary.

5. Develop Proposed Channel Profile

a. Calculate riffle and pool length ranges and averages, L_{rif} and L_{pool}
   i. $L_{rif} = \left[\frac{L_{rif}}{W_{bkf}}\right] \times W_{bkf}$
b. Calculate riffle, pool, run and glide slope ranges and averages
   i. $s_{rif} = \left[\frac{s_{rif}}{s}\right] \times s$
c. Establish longitudinal stations along the thalweg of the new stream channel alignment. Locate the position for each riffle, run, pool and glide along the new thalweg, remembering that pools are located on the outside of the meander bends. Determine the station for the head of each riffle, run, pool and glide and the max pool considering the pool, riffle, run and glide lengths and pool-to-pool spacing established from the reference-reach data.
d. Develop a proposed longitudinal profile using the riffle and pool lengths, depths and slopes for the thalweg and the bankfull stage using the Excel Spreadsheet provided.

6. Hydraulic and Sediment Transport Design Analyses

a. Evaluate average channel velocities and shear stress
b. Check sediment transport competency to ensure equilibrium using entrainment

7. Select Stabilization Measures

a. Identify bank and fill slope need and appropriate protection measures (e.g. J-hooks, log and rock vanes, toe wood revetments, sod mats) and locate on the alignment
b. Identify need and appropriate grade control and diversion structures (e.g. cross-vanes, steps) and locate on plans.