TO: INTERNAL

FROM: STAFF OF THE EXECUTIVE DIRECTOR'S OFFICE

SUBJECT: AVERAGE DENSITY OF MATERIAL THAT COULD BE USED FOR SEDIMENT AUGMENTATION

DATE: JANUARY 6, 2017

I. INTRODUCTION

This memorandum provides an estimate of the average density of material that could be used for sediment augmentation. The estimate was developed using data collected during the geotechnical investigation performed by Twin Rivers Testing and Environmental (Twin Rivers) at the Plum Creek Complex (PCC) in August of 2016. The data, methods and results as they relate to sediment augmentation are described below.

II. DATA & METHODS

Twin Rivers drilled exploratory boreholes at 10 locations on the PCC in August of 2016 (**Figure 1**). Soil samples were obtained from the boreholes using three methods (split spoon, Shelby tube, and grab) and a range of tests (i.e., grain size analyses, permeability tests, density tests, etc.) were performed on the samples. One of the objectives of the investigation and subsequent analyses was to estimate the porosity of the in-situ alluvial sands, which required Twin Rivers to perform minimum and maximum density tests (ASTM D4253 and ASTM D4254, respectively) on grab samples of the alluvial material. . It is important to note that the tests were performed on dry samples and all densities referred to herein are dry densities, unless otherwise noted. The results of the density tests were then used to calculate a sample density of the alluvial material using the equation below:

Equation 1:

$$D_R = \frac{\gamma_{max}(\gamma - \gamma_{min})}{\gamma(\gamma_{max} - \gamma_{min})}$$

Where:

D_R	=	relative density
γ	=	sample density
γ_{min}	=	minimum density
γ_{max}	=	maximum density

Using **Equation 1** above, Twin Rivers assumed a relative density (D_R) value of 0.50 (or 50%), plugged in the results of the density tests for the minimum (γ_{min}) and maximum (γ_{max}) densities, and solved the equation for the sample density (γ) of the material. They then carried out another series of equations to estimate the in-situ porosity of the material. However, the sample density calculated as shown above is of interest to the Executive Director's Office (EDO) of the Platte River Recovery Implementation Program (Program) because it is likely representative of the

density of the material that could be used for sediment augmentation activities near the PCC and elsewhere.

III. RESULTS

The augmentation material that will be used for sediment augmentation activities in the Platte River near the PCC and elsewhere will be the sandy soils within or near the historical channel (**Figure 1**). The material will likely either be pushed into the channel from the bank or excavated from adjacent lands and hauled a short distance to the river. Consequently, the sample densities of the alluvial sands from the four boreholes on the PCC nearest or within the historical channel (d2, d3, d4 and d5 on **Figure 1**) are likely the most representative of the material that will be used for sediment augmentation. Density results from these four boreholes, one of which (d4) is located within the boundary of the historical channel and three (d2, d3, and d5) of which are located along the boundary of the historical channel (**Figure 1**), were used to develop the estimate of the average density of sediment augmentation material.

The maximum, minimum and sample density results from the sand samples from the alluvium at each of the four borehole locations as calculated and reported by Twin Rivers are shown in **Table 1** below. As can be seen, the densities of the alluvial sands are relatively similar between the four locations, which suggests that the properties of the material are relatively uniform and are well represented by an average value. The average maximum, minimum and sample densities of the samples from the four locations are 125.6, 106.4 and 115.3 pounds per cubic foot (lbs/cf), respectively. Sediment augmentation quantities are generally large enough that they are most often discussed in terms of tons and/or cubic yards; therefore, the above values are converted to 1.7, 1.4 and 1.5 tons per cubic yard (tons/cy) for purposes of this memorandum.

Table 1: Densities of the alluvial sand samples from the four boreholes of interest on the Dyer property.

Sample (Depth)	Max Density lbs/cf (ton/cy)	Min Density lbs/cf (ton/cy)	Sample Density lbs/cf (ton/cy)
d2 (15 – 25’)	127.3 (1.72)	109.9 (1.48)	118.0 (1.59)
d3 (15 – 25’)	123.2 (1.66)	105.7 (1.43)	113.7 (1.53)
d4 (20 – 30’)	127.0 (1.71)	109.7 (1.48)	117.8 (1.59)
d5 (15 – 20’)	124.8 (1.68)	100.3 (1.35)	111.6 (1.51)
Average	125.6 (1.70)	106.4 (1.44)	115.3 (1.56)

IV. DISCUSSION

It is recommended that the average sample density of 1.5 tons/cy be used as the estimate of the average density of the material used for sediment augmentation, if the material is to be obtained from the alluvium. This estimate is about 25% larger than the assumed density of sediment augmentation material used in recent Program studies, which is 1.25 tons/cy (The Flatwater Group Inc., 2014; Program, 2016), although it is unclear where this assumed value was first developed or if it has been verified in the field. A value of 1.4 tons/cy has also been previously assumed (The

Flatwater Group Inc., 2010). In considering which value to use, it is important to note that the samples collected by Twin Rivers were done so at depths between 15 ft and 30 ft below grade and outside of the active channel. Thus, when tested, these samples typically had a very high percentage of sands and gravels (i.e., typically > 98%). The densities of these samples could be slightly higher than those of bed and bank material of the river, which would likely contain a greater percentage of fines (although the percentage would still be relatively small). Typical median grain sizes of the alluvial sands sampled by Twin Rivers (0.7 mm to 2.5 mm) are within the range of observed median grain sizes of the sands in the Platte River's main channel, which were reported to range from about 0.7 to 2.1 mm (HDR et al., 2011). So, it is likely that these densities are relatively representative of that of the material in the main channel.

To date, this is the best available Program data regarding the density of the alluvial material that could be used for sediment augmentation. It is also likely a good estimate of the density of the existing bed and bank material within the active channel. Uncertainties in the developed average density value mostly pertain to assumptions that the alluvial material is consistent with the channel bed and bank material (which was addressed above) and that the relative density of the in-situ material is about 0.50 (or 50%). The validity of the relative density assumption could be tested against alternative methods of estimating relative density, but those alternative methods require additional parameters that would need to be estimated (e.g., compressibility factor, age of soil, overconsolidation factor, etc.) (Kulhawy and Mayne, 1990). Instead, it is recommended that the user be aware that the average density of the alluvial material ranges from about 1.4 tons/cy (in a relative loose state) to about 1.8 tons/cy (in a highly compacted state) and is likely about 1.5 tons/cy on average. If more accurate estimates are desired, it is recommended that the actual material at each sediment augmentation location be sampled and tested in a manner similar to that of the alluvium.

V. REFERENCES

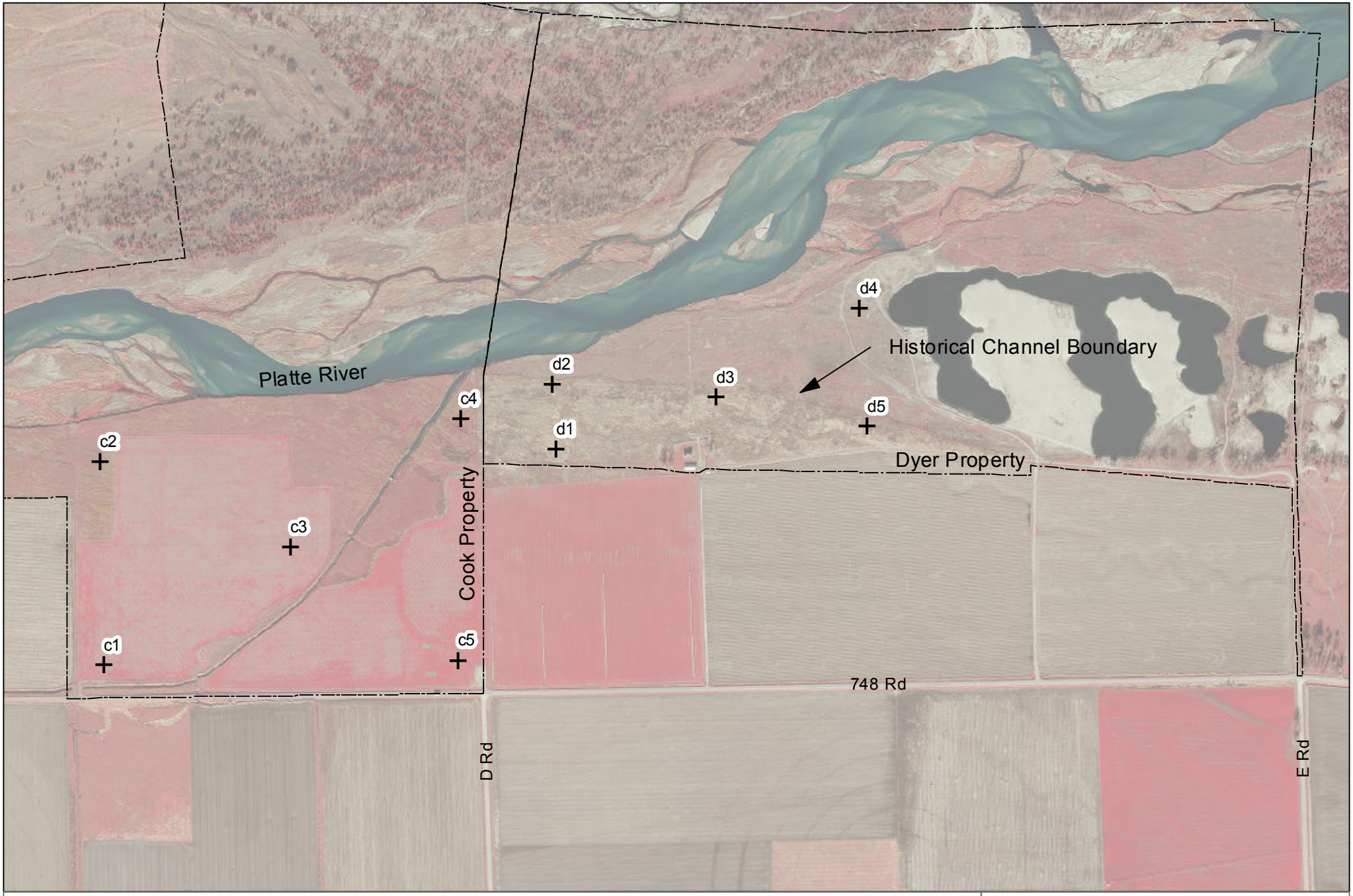
HDR Engineering, Inc., in association with Tetra Tech, Inc. and The Flatwater Group, Inc. 2011. 1-D Hydraulic and Sediment Transport Model Final Hydraulic Modeling Technical Memorandum. Prepared for Platte River Recovery Implementation Program.

Kulhawy, F.H. and P.W. Mayne. 1990. Manual on Estimating Soil Properties for Foundation Design. Cornell University: Prepared for Electric Power Research Institute.

Platte River Recovery Implementation Program (Program). 2016. Implementation Design for Full-Scale Sediment Augmentation (Draft). Office of the Executive Director.

The Flatwater Group, Inc., in association with HDR Engineering, Inc. and Tetra Tech, Inc. 2014. Sediment Augmentation Final Pilot Study Report. Prepared for the Platte River Recovery Implementation Program.

The Flatwater Group, Inc., in association with HDR Engineering, Inc. and Tetra Tech, Inc. 2010. Platte River from the Lexington to Odessa Bridges: Sediment Augmentation Experiment Alternatives Screening Study Summary Report (Final). Prepared for the Platte River Recovery Implementation Program.



Plum Creek Geotechnical Investigation Map

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Legend

+ Bore Hole Locations

Property Boundaries

0 500 1,000 Feet

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Figure: 1

Date: 11/30/2016