Supplemental Suggestions for Incorporation into MFR: Materials Used by Emergency Management Branch

3. Materials Descriptions.

3.1 References:

3.1.1 EM 1110-2-2302 dated October 1990, Construction with Large Stone"
3.1.2 EM 1110-2-1601 dated Jun 1994 "Chapter 3 of Hydraulic Design of Flood Control Channels"
3.1.3 CE Guide Specification – 02380 August 1999 "Stone, Channel, Shoreline/Coastal Protection For Structures"
3.1.4 ASTM D 4992 – Evaluation of Rock to be Used for Erosion Control

3.2 Specifications for Riprap (Stone). **It is important that each rock piece accepted for use be composed of hard, strong, durable materials that will not slake or deteriorate on exposure to the action of water or atmosphere**. To achieve these criteria the Seattle District uses several means to ensure that quality stone is delivered and placed on a project. The three most utilized means for acceptance of stone are quarry inspection (preferably by a Corps geologist), laboratory test results (preferably by a Corps validated laboratory), and visual examination of rock delivered to the project site(preferably done by a Corps Representative/Inspector).

3.2.1 Visual Examination. A typical stone specification will begin with the following description: Stone shall be clean and angular, and longest dimension of any stone shall not exceed three times the shortest dimension. Stone shall be of suitable quality to ensure permanence to the structure and in the climate in which it is to be used. Stone shall be free of expansive or other materials that could cause accelerated deterioration by exposure to project climatic conditions. **Stone shall be free of cracks, blast fractures, bedding, seams and other defects that would tend to increase its deterioration from natural causes. Inspections for cracks, fractures, seams, bands of minerals, deleterious materials, and defects shall be made by visual examination**. A hairline crack that is defined as being detrimental shall have a minimum width of 0.1 mm and shall be continuous for one-third the dimension of at least two sides of the stone. Stone shall be free of bands of minerals and deleterious materials that would result in breakage or reduction of specified stone weights or dimensions during or after placement. Each stone shall have sufficiently uniform physical properties throughout so that all portions of the stone will meet the specified requirements.

3.2.2 Quarry Inspection. Geology and Instrumentation Section (EC-TB-GE) uses a check list to ensure the necessary information is gathered during a quarry inspection. Another equally important checklist is available in ASTM D 4992. Keep in mind that rocks within Pacific Northwest quarries are mostly heterogeneous. Rock selected for laboratory testing is generally not indicative of the entire quarry so it is important to delineate on a sketch map the location where rock samples are collected from. As part of

the quarry inspection a drop test proves quite valuable. The drop test provides an immediate evaluation of durability of large stones that can be expected during handling. If equipment is available to perform such tests during the quarry inspection the District recommends several suites of stone drop tests be accomplished. Stone should be dropped from a bucket or other means from a height of not less than half the average diameter of the stone onto a rigid surface or a second stone of comparable size. Failure criteria are the development of new cracks, opening of old cracks, and the loss of a piece from the surface of the stone. Each stone should be dropped five times for evaluation purposes with examination after each drop.

3.3.3 Laboratory Test Results. Reference Table 6-1 in EM 1110-2-2302 for recommended testing. For Seattle District the usual specified tests are: a) Specific Gravity; b) Absorption; c) Accelerated Expansion; d) Freeze-Thaw; e) Wet-Dry; f) Magnesium Sulfate Soundness; g) Los Angeles Abrasion Resistance; and h) Petrographic Analysis. Freeze-Thaw testing is usually waived for salt-water projects. Quarry rock test results meeting specification are not always indicative that the rock is durable. This was the case in 1994 for rock work at LaConner, WA. The rock from Pacific Quarry in Mount Vernon passed the suite of laboratory tests specified in the contract, yet when handled and placed at the job site the rock broke readily due to small incipient cracks that were plainly visible when the rock was wet. Therefore, the Pacific Quarry rock failed durability criteria (by visual examination) and durable rock had to be trucked a longer distance from Granite Falls.

4. Seattle District General Guidance for Riprap Classifications:

RIP RAP GRADATION- PACIFIC NORTHWEST RIVERS
(Slopes 1V on 2H)

Class	**I**	**II**	**III**	**IV**	**V**
Rip Rap Thickness	**18”**	**24”**	**30”**	**36”**	**48”**
Rock Size Range	25-150#	25-500#	25-800#	25-1000#	25-1800#
50% size	50#	200#	300#	400#	750#
90% larger than	25#	100#	150#	200#	350#
10% sizes	25#	25-100#	25-150#	25-200#	25-350#
Velocity f.p.s (mid channel)	6-10	10-14	14-16	17	18
Tolerance	+4”	+6”	+8”	+12”	+16”

Notes:
1. Assume rock weight of 165 pounds per cubic foot [165 pcf/62.43 pcf = 2.63 specific gravity (BSSD)].
2. For slope up to 1V on 1.5H use same class with double the thickness
3. Assume that the length/width ratio of the rock is no greater than 3.
4. Riprap gradation for use on the outside bank of a bend should be based on a selection velocity that is twice the average channel velocity.
5. Riprap gradation for use on the banks of a relatively straight reach should be based on a selection velocity that is 1.5 times the average channel velocity.
6. Riprap gradation for channel bottoms should be based on the average channel velocity.