NATIONAL MARINE FISHERIES SERVICE
NATIONAL GRAVEL EXTRACTION GUIDANCE

I. INTRODUCTION

The National Marine Fisheries Service (NOAA Fisheries) is responsible for protecting, managing and conserving marine, estuarine, and anadromous fish resources and their habitats. The watersheds of the United States where sand and gravel mining takes place provide essential spawning and rearing habitat for anadromous fishes including salmon, shad, sturgeon, and striped bass.

A national guidance document on gravel extraction is necessary because extraction in and near anadromous fish streams can cause many adverse impacts to fishes and their habitats. Potential impacts include: direct harm to trust species; loss or degradation of spawning beds and juvenile rearing habitat; migration blockages; channel widening, shallowing, and ponding; loss of hydrologic and channel stability; loss of pool/riffle structure; increased turbidity and sediment transport; increased bank erosion and/or stream bed downcutting; and loss or degradation of riparian habitat. The impacts can extend far beyond the mining site, and stream recovery time can take decades.

In the context of the Federal trust responsibilities, as defined in the collective body of Federal law and rule, NOAA Fisheries must ensure that gravel extraction operations eliminate or minimize, to the greatest extent possible, any adverse impacts to anadromous fishes and their habitats.

This Guidance does not specify the measures, if any, that would need to be implemented by parties engaged in gravel extraction activities in any given case to comply with applicable statutory requirements. In formulating its recommendations or prescriptions, NOAA Fisheries will determine the acceptable means of demonstrating compliance with statutory requirements based on information available to the agency, as appropriate under the circumstances presented. As such, the language of the Guidance should not be read to establish any binding requirements on agency staff or the regulated community.

The objective of the NOAA Fisheries Gravel Guidance is to assist NOAA Fisheries staff in determining whether proposed gravel extraction operations will be conducted in a manner consistent with Federal law, and that eliminates or minimizes any adverse impacts to anadromous fishes and their habitats. NOAA Fisheries recommends that gravel extraction operations not interfere with anadromous fish migration, spawning, or rearing; nor negatively impact viable existing or historic anadromous fish habitat. Further, it is recommended that individual gravel extraction operations be judged in the context of their spatial, temporal, and cumulative impacts; and that potential impacts to habitat be viewed from a watershed management perspective. Although this Guidance applies nationwide, it is not to be regarded as static or inflexible, as specific project recommendations should be made specific to individual sites, streams, and watersheds.

A suite of Federal laws assigns NOAA Fisheries the responsibility and authority to address gravel extraction activities, when the activities affect marine or anadromous fish, or their habitats. These authorities are summarized in Appendix I, and include the Endangered Species Act (ESA), Clean Water Act (CWA), National Environmental Policy Act (NEPA), the Magnuson Fishery Conservation and Management Act, and the accompanying implementing regulations of each law.

This Draft Guidance document is available for public review until May 3, 2004, and will be revised based on comments received. Comments or questions should be brought to the attention of Kerry Griffin at the NOAA Fisheries Office of Habitat Conservation in Silver Spring, Maryland (301-713-4300; kerry.griffin@noaa.gov). Comments may also be faxed to 301-713-4305.

II. SCOPE OF GRAVEL GUIDANCE

This Guidance document applies to freshwater and tidal reaches of rivers and streams; tidal sloughs, and their associated wetlands and riparian zones where anadromous fish are currently or were historically present.

The types of gravel extraction activities referred to in this Gravel Guidance generally entail commercial gravel mining using heavy equipment; i.e., removing or obtaining a supply of gravel for industrial uses, such as road construction material, concrete aggregate, fill, and landscaping. Gravel can also be removed for maintenance dredging and flood control. Gravel extraction often occurs at multiple times and at multiple sites along a given stream, resulting in impacts that are likely to be both chronic and cumulative. When the rate of gravel extraction exceeds the rate of natural deposition over an extended time period, a net loss occurs due to the cumulative loss of gravel (Oregon Water Resources Research Institute [OWRRI] 1995).

This Gravel Guidance document addresses three types of instream gravel mining, which Kondolf (1993, 1994a, 1997, 1998) describes as follows: dry-pit and wet-pit mining in the active channel, and bar skimming (or "scalping"). Dry-pit refers to pits excavated on dry ephemeral stream beds and exposed bars with conventional bulldozers, scrapers, and loaders. Wet-pit mining involves the use of a dragline or hydraulic excavator to remove gravel from below the water table or in a perennial stream channel. Bar skimming or scalping removes the surface from gravel bars without excavating below the low water flow level.

In addition to instream mining, this Guidance document also addresses another method, which Kondolf (1993, 1994a, 1997, 1998a) describes as the excavation of pits on the adjacent floodplain or river terraces. Dry pits are located above the water table. Wet pits are below, depending on the elevation of the floodplain or terrace relative to the baseflow water elevation of the channel. Their isolation from an adjacent active channel may be only short term. During a sudden change in channel course during a flood, or as part of gradual migration, the channel may shift into the gravel pits (Kondolf 1998a). Because floodplain pits can become integrated into the active channel, Kondolf (1993, 1994a) suggests that they should be regarded as existing instream if considered on a time scale of decades.

III. ENVIRONMENTAL EFFECTS OF GRAVEL EXTRACTION

Extraction of alluvial material from within or near a stream bed has a direct impact on the stream's physical habitat parameters such as channel geometry, bed elevation, substrate composition and stability, instream roughness elements (large woody debris, boulders, etc.) depth, velocity, turbidity, sediment transport, stream discharge, and temperature (Rundquist 1980; Pauley et al. 1989; Kanehl and Lyons 1992; Kondolf 1994a, b, 1997, 1998a; OWRRI 1995; Brown et al. 1998; Florsheim et al. 1998; Meador and Layher 1998). OWRRI (1995) states that:

> Channel hydraulics, sediment transport, and morphology are directly affected by human activities such as gravel mining and bank erosion control. The immediate and direct effects are to reshape the boundary, either by removing or adding materials. The subsequent effects are to alter the flow hydraulics when water levels rise and inundate the altered features. This can lead to shifts in flow patterns and patterns of sediment transport. Local effects also lead to upstream and downstream effects.

Altering these habitat parameters can have deleterious impacts on instream biota, food webs, and the associated riparian habitat (Sandecki 1989; Kanehl and Lyons 1992; Koski 1993; Spence et al. 1996; Brown et al. 1998). For example, impacts to anadromous fish populations due to gravel extraction can include: reduced fish populations in the disturbed area, replacement of one species by another, replacement of one age group by another, or a shift in the species and age distributions (Moulton 1980). Changes in physical habitat characteristics of aquatic systems can alter competitive interactions within and among species; similarly, changes in temperature or flow regimes may favor species that prey on anadromous fish populations (Spence et al. 1996). In general terms, Rivier and Seguier (1985) suggest that the detrimental effects to biota resulting from bed material mining are caused by two main processes: (1) Alteration of the flow patterns resulting from modification of the river bed, and (2) An excess of suspended sediment. OWRRI (1995) adds:

> Disturbance activities can disrupt the ecological continuum in many ways. Local channel changes can propagate upstream or downstream and can trigger lateral changes as well. Alterations of the riparian zone can allow changes in-channel [*sic*] conditions that can impact aquatic ecosystems as much as some in-channel activities.
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> One consequence of the interconnectedness of channels and riparian systems is that potential disruptions of the riparian zone must be evaluated when channel activities are being evaluated. For example, aggregate mining involves the channel and boundary but requires land access and material storage that could adversely affect riparian zones; bank protection works are likely to influence riparian systems beyond the immediate work area.

It should be emphasized that cobble and gravel substrates are in and of themselves extremely important habitat for anadromous fish including salmon, shad, striped bass, and sturgeon. Gravel complexes are highly functioning and critical habitat elements, with protective crevices and well-oxygenated interstitial spaces important for anadromous fish egg hatching, and containing rich assemblages of benthic nutrients used as food for developing fish larvae; and macroinvertebrates for post-larval juveniles. Gravel complex habitat is relatively rare and under threat in southeastern riparian systems.

The potential effects of gravel extraction activities on stream morphology, riparian habitat, and anadromous fishes and their habitats are summarized as follows:

1. **Instream gravel mining disrupts the preexisting balance between sediment supply and transporting capacity, and can result in channel incision and bed degradation** (Kondolf 1997, 1998a; Florsheim et al. 1998; Meador and Layher 1998). This is partly because gravel "armors" the bed, stabilizing banks and bars, whereas removing this gravel causes excessive scour and sediment movement (Lagasse et al. 1980; OWRRI 1995; Kondolf 1997, 1998a). Degradation and erosion can extend upstream and downstream of an individual extraction operation, and can result from bed mining either in or above the low-water channel (Collins and Dunne 1990; Kanehl and Lyons 1992; Kondolf 1994a, b, 1997, 1998a; OWRRI 1995; Pringle 1997; Brown et al. 1998). For example, headcutting (upstream erosion), increased velocities, concentrated flows, and bank undercutting with subsequent loss of riparian habitat can occur upstream of the extraction site due to a steepened river gradient (Kanehl and Lyons 1992; OWRRI 1995; Kondolf 1997; Pringle 1997), resulting in the release of additional sediment to downstream reaches, where the channel may aggrade and become unstable (Kondolf 1997). Degradation can deplete the entire depth of gravel on a channel bed, exposing other substrates that may underlie the gravel, which would reduce the amount of usable anadromous spawning habitat (Collins and Dunne 1990; Kondolf 1994a, 1997, 1998a; OWRRI 1995). For example, gravel removal from bars may cause downstream bar erosion if they subsequently receive less bed material from upstream than is being carried away by fluvial transport (Collins and Dunne 1990). Thus, gravel removal not only impacts the extraction site, but also may reduce gravel delivery to downstream spawning areas (Pauley et al. 1989; Brown et al. 1998). Gravel mining itself often selectively removes gravels of approximately the same sizes as needed by salmonids for spawning [median diameters of between 15-45 mm (Kondolf and Wolman 1993); see also Kondolf (2000)], again reducing the amount of usable spawning habitat.

2. **Instream gravel extraction can cause increases in suspended sediment, sediment transport, water turbidity, and gravel siltation** (Kanehl and Lyons 1992; OWRRI 1995; Kondolf 1997). The most significant change in the sediment size distribution resulting from gravel removal is a decrease in sediment size caused by fine material deposition into the site (Rundquist 1980). Brown et al. (1998) also note that the fine material can travel long distances downstream as a plume of turbidity while the gravel is being removed, and during floods, turbidity is likely to be higher than normal for even longer distances downstream due to the higher flow rate and increased entrainment of sediments as a result of channel deformation. As reviewed by Everest et al. (1987), fine sediments in particular are detrimental to salmonid redds (nests) because (1) blockage of interstitial spaces by deposited silt prevents oxygenated water from reaching the incubating eggs within the redd, as well as the removal of waste metabolites; (2) embryos or sac fry can be smothered by high concentrations of suspended sediments that enter the redd; and (3) emerging fry can become trapped if enough sediment is deposited on the redd (Koski 1966, 1981; Chapman 1988; Reiser and White 1988; Waters 1995). High silt loads may also inhibit larval, juvenile and adult behavior, migration, or spawning (Snyder 1959; Cordone and Kelly 1961; Koski 1975; Bisson and Bilby 1982; Berg and Northcote 1985; Bjornn and Reiser 1991; Kanehl and Lyons 1992; Servizi and Martens 1992; OWRRI 1995). Excessive amounts of suspended material can

abrade the protective slime coatings on the surface of the fish and their gills, which can lead to increased bacterial and fungal infections (Cordone and Kelly 1961; Rivier and Seguier 1985). Increased suspended sediments may block vision and impair feeding (Sigler et al. 1984; Rivier and Seguier 1985). Siltation, substrate disturbances and increased turbidity also negatively affect the invertebrate food sources of fishes and severely alter the aquatic food web, thus affecting the growth and survival of the fish (Kanehl and Lyons 1992; OWRRI 1995; Spence et al. 1996; Brown et al. 1998).

3. **Bed degradation changes the morphology of the channel and increases channel instability** (Moulton 1980; Rundquist 1980; Sullivan et al. 1987; Collins and Dunne 1990; Kanehl and Lyons 1992; Kondolf 1994a, b, 1997; OWRRI 1995; Brown et al. 1998; Florsheim et al. 1998). Gravel extraction can cause a diversion or a high potential for diversion of flow through the gravel removal site (Rundquist 1980). Mined areas that show decreased depth or surface flow could result in migration blockages during low flows (Moulton 1980). This may compound problems in many areas where flows may already have been altered by hydropower operations and irrigation. Even if the gravel extraction activity is conducted away from the active river channel during low water periods, substrate stability and channel morphology outside the excavated area's perimeter could be affected during subsequent high water events (Kondolf 1997, 1998a). As active channels naturally meander, the channel may migrate into the excavated area (Kondolf 1998a). Also, ponded water isolated from the main channel may strand or entrap fish carried there during high water events (Moulton 1980; Palmisano 1993; Kondolf 1997). Fish in these ponded areas could experience higher temperatures, lower dissolved oxygen, increased predation compared to fish in the main channel, an altered food web, desiccation if the area dries out, and freezing (Moulton 1980; Spence et al. 1996; Kondolf 1997, 1998a).

4. **Gravel bar skimming can significantly impact aquatic habitat.** Bar skimming creates a wide flat cross section, then eliminates confinement of the low flow channel, which can then result in a thin sheet of water at baseflow (Kondolf 1994a, 1997). Sediment transport efficiency may be reduced through the unconfined reach, causing deposition and subsequent instability (Kondolf 1998a). Removal of the bar may alter channel hydraulics upstream as well as at the gravel extraction site (Kondolf 1998a). Bar skimming can also remove the gravel "pavement," leaving the finer subsurface particles vulnerable to entrainment (erosion) at lower flows (Kondolf 1994a, 1998a; OWRRI 1995). A related effect is that bar skimming lowers the overall elevation of the bar surface and may reduce the threshold water discharge at which sediment transport occurs (OWRRI 1995). Salmon redds downstream are thus susceptible to deposition of displaced, surplus alluvial material, resulting in egg suffocation or suppressed salmon fry emergence, while redds upstream of scalped bars are vulnerable to regressive erosion (Pauley et al. 1989). Gravel bar skimming also appears to reduce the amount of side channel areas, which can result in the reduction and/or displacement of juvenile salmonid fishes that use this habitat (Pauley et al. 1989). All these effects can be particularly problematic if upstream flows are already reduced by diversions and dams.

5. **Operation of heavy equipment in the channel bed can directly destroy spawning habitat, rearing habitat, the juveniles themselves, and macroinvertebrates, and produce increased**

turbidity and suspended sediment downstream (Forshage and Carter 1973; Kondolf 1994a). Additional disturbances to redds may occur from increased foot and vehicle access to spawning sites, due to access created initially for gravel extraction purposes (OWRRI 1995). Also, heavy equipment is powered by diesel fuel and lubricated by other hazardous petroleum products, leading to the potential for toxic chemical spills.

6. **Stockpiles and overburden left in the floodplain can alter channel hydraulics during high flows.** During high water, the presence of stock piles and overburden can cause fish blockage or entrapment, and fine material and organic debris may be introduced into the water, resulting in downstream sedimentation (Follman 1980).

7. **Removal or disturbance of instream roughness elements during gravel extraction activities can negatively affect both quality and quantity of anadromous fish habitat.** Instream roughness elements, including the gravel itself and large woody debris, play a major role in providing structural integrity to the stream or river ecosystem and provide critical habitat for salmonids (Koski 1992; Naiman et al. 1992; Franklin et al. 1995; Murphy 1995; OWRRI 1995; Abbe and Montgomery 1996; Collins and Dunne 2002; Collins et al. 2002). These elements are important in controlling channel morphology and stream hydraulics, in regulating the storage of sediments, gravel and particulate organic matter, and in creating and maintaining habitat diversity and complexity (Franklin 1992; Koski 1992; Murphy 1995; OWRRI 1995). Large woody debris in streams creates pools and backwaters that salmonids use as foraging sites, critical overwintering areas, refuges from predation, and spawning and rearing habitat (Koski 1992; OWRRI 1995). Large wood jams at the head of gravel bars can anchor the bar and increase gravel recruitment behind the jam (OWRRI 1995). Loss of large woody debris from gravel bars can also negatively impact aquatic habitat (Weigand 1991; OWRRI 1995). The importance of large woody debris has been well documented, and its removal results in an immediate decline in salmonid abundance (e.g., see citations in Koski 1992; Franklin et al. 1995; Murphy 1995; OWRRI 1995). It is also important to remember that gravel deposits are themselves instream roughness elements. This understanding is key to recognizing that the same type of effects analysis as is applied to the removal of large woody debris; i.e., linking hydraulics and habitat, is also applicable for gravel deposits underwater or on bars.

8. **Destruction of the riparian zone during gravel extraction operations can have multiple deleterious effects on anadromous fish habitat.** The importance of riparian habitat to anadromous fishes (Koski 1993) should not be underestimated. For example, Koski (1992) states that a stream's carrying capacity to produce salmonids is controlled by the structure and function of the riparian zone. The riparian zone includes stream banks, riparian vegetation and vegetative cover. Damaging any one of these elements can cause stream bank destabilization, resulting in increased erosion, sediment and nutrient inputs, and reduced shading and bank cover leading to increased stream temperatures. Destruction of riparian trees also means a decrease in the supply of large woody debris. This results in a loss of instream habitat diversity caused by removing the source of materials responsible for creating pools and riffles, which are critical for anadromous fish growth and survival, as outlined in Number 7, above (Koski 1992; Murphy 1995; OWRRI 1995).

Gravel extraction activities can damage the riparian zone in several ways:

- If the floodplain aquifer discharges into the stream, groundwater levels can be lowered because of channel degradation. Lowering the water table can destroy riparian vegetation (Collins and Dunne 1990).
- Long-term loss of riparian vegetation can occur when gravel is removed to depths that result in permanent flooding or ponded water. Also, loss of vegetation occurs when gravel removal results in a significant shift of the river channel that subsequently causes annual or frequent flooding into the disturbed site (Joyce 1980).
- Heavy equipment, processing plants, and gravel stockpiles at or near the extraction site can destroy riparian vegetation (Joyce 1980; Kondolf 1994a; OWRRI 1995). Heavy equipment also causes soil compaction, thereby increasing erosion by reducing soil infiltration and causing overland flow. As mentioned above, the use of heavy equipment also leads to the increased risk of chemical pollution; hazardous chemicals may also be used in nearby sediment processing plants. In addition, roads, road building, road dirt and dust, and temporary bridges can also impact the riparian zone.
- Removal of large woody debris from the riparian zone during gravel extraction activities negatively affects the plant community (Weigand 1991; OWRRI 1995). Large woody debris is important in protecting and enhancing recovering vegetation in streamside areas (Franklin et al. 1995; OWRRI 1995).
- Rapid bed degradation may induce bank collapse and erosion by undercutting and by increasing the heights of banks (Collins and Dunne 1990; Kondolf 1994a, 1997).
- Portions of incised or undercut banks may be removed during gravel extraction, resulting in reduced vegetative bank cover, causing reduced shading and increased water temperatures (Moulton 1980).
- Banks may be scraped to remove “overburden” to reach the gravel below. This may result in destabilized banks and increased sediment inputs (Moulton 1980).
- The reduction in size or height of bars can cause adjacent banks to erode more rapidly or to stabilize, depending on how much gravel is removed, the distribution of removal, and on the geometry of the particular bed (Collins and Dunne 1990).

IV. RECOMMENDATIONS

The following recommendations do not specify the measures, if any, that would need to be implemented by parties engaged in gravel extraction activities in any given case to comply with applicable statutory requirements. In formulating its recommendations or prescriptions, NOAA Fisheries will determine the acceptable means of demonstrating compliance with statutory requirements based on information available to the agency, as appropriate under the circumstances presented. As such, the language of the Guidance should not be read to establish any binding requirements on agency staff or the regulated community. The recommendations should not be regarded as static or inflexible, and are meant to be revised as the science upon which they are based improves and areas of uncertainty are resolved.

Furthermore, the recommendations are meant to be adapted for regional or local use, so a degree of flexibility in their interpretation and application is necessary.

In general terms, gravel extraction operations located in or immediately adjacent to streams have greater impacts to anadromous fish resources and habitats than operations located further away from the stream. Therefore, NOAA Fisheries recommends that all reasonable efforts be made to identify aggregate sources in the inactive floodplain before deciding to site project operations in the stream channel. This is commensurate with the CWA section 404 rationale of *avoiding* impacts, *minimizing* (when not reasonably possible to avoid), and then *mitigating* (when not reasonably possible to minimize).

If no reasonable floodplain/terrace extraction sites are available, the operator may be forced to locate operations within the active channel. In these cases, NOAA Fisheries recommends that project operations be carefully designed to minimize impacts to trust resources, including habitat. Bar skimming is generally preferable to wet-pit mining (deep water dredging) within the active channel. In either case, we recommend that many factors be taken into consideration when designing project operations. The recommendations below present generic considerations. Each project should be considered in its own context, based on project design, stream type, natural resources, and cumulative impacts. NOAA Fisheries regions are encouraged to adopt more detailed guidelines tailored to each region.

1. **NOAA Fisheries recommends that upland rock sources, terraces and inactive floodplain be used preferentially to active channels, their deltas and floodplain.** It is recommended that hardrock quarries or gravel extraction sites be situated outside the active floodplain and that the gravel is not excavated from below the water table. In other words, dry-pit mining on upland outcrops, terraces or floodplain is preferable to any of the alternatives. In addition, it is recommended that operators not divert streams to create an inactive channel for gravel extraction purposes, and formation of isolated ponded areas that cause fish entrapment be avoided. In all cases, it is recommended that efforts be made to minimize the need for crossing active channels with heavy equipment.

2. **NOAA Fisheries recommends that pit excavations located on adjacent floodplain or terraces be separated from the active channel by a buffer designed to maintain this separation for several decades.** As previously discussed in Section II, the active channel can shift into the floodplain pits ('channel capture'), therefore Kondolf (1993, 1994a) recommends that the pits be considered as potentially instream when viewed on a time scale of decades. Consequently, it is recommended that buffers or levees that separate the pits from the active channel be designed to withstand long-term channel migration, flooding or inundation; and to avoid fish entrapment. Kondolf (1997) reminds us that:

   > A river channel and floodplain are dynamic features that constitute a single hydrologic and geomorphic unit characterized by frequent transfers of water and sediment between the two components. The failure to appreciate the integral

connection between floodplain and channel underlies many environmental problems in river management today.

Generally, the physical setback of the pit from the channel should be based on several channel widths, or on the meander belt. Pit size should also be considered in determining appropriate buffers. Larger pits have the capacity to absorb a much greater volume of sediment than smaller pits, upon pit capture.

3. **NOAA Fisheries recommends that larger rivers and streams be used preferentially to small rivers and streams.** Larger systems generally have more gravel and a wider floodplain, and a proportionally smaller disturbance in large systems will reduce the overall impact of gravel extraction (Follman 1980). On a smaller river or stream, the location of the extraction site is more critical because of the limited availability of exposed gravel deposits and the relatively narrower floodplain (Follman 1980). In either case, NOAA Fisheries recommends that the extraction volume relative to course sediment load be low.

4. **NOAA Fisheries recommends that braided river systems be used preferentially to other river systems.** The other systems, listed in the order of increasing sensitivity to physical changes caused by gravel extraction activities, are: split, meandering, sinuous, and straight (Rundquist 1980). Because braided river systems are dynamic and channel shifting is a frequent occurrence, theoretically, channel shifting resulting from gravel extraction might have less of an overall impact because it is analogous to a naturally occurring process (Follman 1980). However, gravel extraction from braided streams is still considered instream extraction, and it is recommended that it be avoided.

5. **NOAA Fisheries recommends that instream gravel removal quantities be strictly limited so that gravel recruitment and accumulation rates are sufficient to avoid extended impacts on channel morphology and anadromous fish habitat.** While this is conceptually simple, annual gravel recruitment to a particular site is, in fact, highly variable and not well understood. (Recruitment is the rate at which bedload is supplied from upstream to replace the extracted material.) Kondolf (1993, 1994b) dismisses the common belief that instream gravel extraction can be conducted safely so long as the rate of extraction does not exceed the rate of replenishment. Kondolf (1993, 1994b) states that this approach to managing instream gravel extraction is flawed because it fails to account for the upstream/downstream erosional effects that change the channel morphology as soon as gravel extraction begins. In addition, Kondolf (1993, 1994b, 1997) reiterates that flow and sediment transport for most rivers and streams is highly variable from year-to-year, thus an annual average rate may be meaningless. An "annual average deposition rate" could bear little relation to the sediment transport regimes in a river in any given year. Moreover, sediment transport processes are very difficult to measure and to model, so estimates of bedload transport may prove unreliable (Kondolf 1997). These problems and uncertainties indicate a need for cautious interpretation of sediment yield results, and the conservative application of volume limitations on extraction projects. Any gravel removal on streams or rivers that have a recent history of eroding bars or banks; or streambed lowering is not recommended.

Collins and Dunne (1990) recommend that appropriate rates and locations for instream gravel extraction should be determined on the basis of:

a. The rate of upstream recruitment;
b. Whether the river bed elevation under undisturbed conditions remains the same over the course of decades, or if not, the rate at which it is aggrading or degrading;
c. Historic patterns of sediment transport, bar growth, and bank erosion in particular bends;
d. Prediction of the specific, local effects of gravel extraction on bed elevations, and the stability of banks and bars. The prediction should take into account an analysis of present or past effects of gravel extraction at various rates;
e. A determination of the desirability or acceptability of the anticipated effects.

In addition, it is recommended that the habitat values of remaining (or newly recruited) sediments be functionally adequate or equivalent for the purposes of spawning, rearing, benthic invertebrate production, etc. Upstream recruitment is ineffective if the necessary ecological functions are not replaced or restored.

6. **NOAA Fisheries recommends that gravel bar skimming be allowed only under restricted conditions.** (See Section III, Number 4, for the environmental impacts of gravel bar skimming.) It is recommended that:
   - Gravel is removed only during low flows and from strictly-defined areas above the low-flow water level
   - Berms and buffer strips are used to control stream flow away from the site and to provide for continued migratory habitat
   - The final grading of the gravel bar does not significantly alter the flow characteristics of the river during periods of high flows (OWRRI 1995)
   - Bar skimming operations are monitored to ensure that they are not adversely affecting low-flow channel morphology or gravel recruitment downstream from the site
   - Geomorphic features are monitored using methods that quantify their physical dimensions and changes at appropriate time scales. This will likely include densely spaced cross-sections to cover the geomorphic features, topographic mapping techniques that do not rely solely on cross-sections but follow terrain features, and modern mapping techniques that grid entire areas with equally spaced data
   - Any gravel removal on streams or rivers that have a recent history of eroding bars or banks, or streambed lowering be discouraged

7. **NOAA Fisheries recommends that prior to gravel removal, a thorough review of sediments and point and non-point sources of contaminants be conducted.** Toxic compounds from a variety of sources (municipalities, manufacturing plants, hardrock mines, etc) may be present in sediments, and can be released into the stream when disturbed during gravel extraction operations. It is recommended that testing of sediments be conducted to detect metals, dioxins, herbicides, pesticides, other organic compounds (DDT, PCBs, etc), and residual acid or heavy metal drainage from hardrock mining operations; and that during project operations, extracted aggregates and sediments not be washed directly in the stream or river or within the riparian zone.

In addition, it is recommended that an assessment of contaminant sources be completed to assist in determining potential problems with contaminated sediments. Sources can include farming, mining, National Pollutant Discharge Elimination System (NPDES)-permitted activities, forestry, sewage treatment plants, and other municipal infrastructure.

To minimize the suspension of sediments, it is recommended that measures be taken to contain turbidity plumes, and to avoid excessive disturbance of sediments. Turbidity curtains can be effective, depending on the characteristics of the site. It is also recommended that turbidity levels do not exceed maximum allowable turbidity limits for anadromous fish and their prey.

8. **NOAA Fisheries recommends that removal or disturbance of instream roughness elements during gravel extraction activities be avoided, and that those that are disturbed be replaced or restored.** As previously stated in Section III, Number 7, instream roughness elements, particularly large woody debris, are critical to stream and river ecosystem functioning. This may be particularly true in small streams where large woody debris plays a relatively greater role in channel morphology and sediment dynamics than in larger streams or rivers. In addition, it is recommended that gravel itself be considered an instream roughness element, and that consideration be given to leaving similar-sized gravel in the streambed, in addition to replacing large woody debris.

9. **NOAA Fisheries recommends that gravel extraction operations be managed to avoid or minimize damage to stream/river banks and riparian habitats.** It is recommended that:
   - Gravel extraction in vegetated (or those that would be vegetated without repeated anthropogenic disturbances), and riparian areas be avoided
   - Gravel pits located on adjacent floodplain not be excavated below the water table
   - Berms and buffer strips in the floodplain that keep active channels in their original locations or configurations be maintained for several decades (as in Number 2, above)
   - Undercut and incised vegetated banks not be altered
   - Large woody debris in the riparian zone be left undisturbed or replaced when moved
   - All support and processing operations (e.g., gravel washing) be done outside the riparian zone
   - Gravel stockpiles, overburden and/or vegetative debris not be stored within the riparian zone
   - Operation and storage of heavy equipment within riparian habitat be restricted
   - Access roads not encroach into the riparian zones
   - Riparian zone protection extend well upstream and downstream from the project site when possible because the erosional effects of instream aggregate mining can be manifested miles upstream and downstream from the site of operations

10. **NOAA Fisheries recommends that the cumulative impacts of gravel extraction operations to anadromous fishes and their habitats be addressed by the Federal, state, and local resource management and permitting agencies; and considered in the permitting process.** The cumulative impacts on anadromous fish habitat caused by multiple extractions and sites along a given stream or river are compounded by other riverine impacts and land use disturbances in the watershed. These additional impacts may be caused by river diversions/impoundments, flood

control projects, logging, grazing, and channel/riparian encroachment. The technical methods for assessing, managing, and monitoring cumulative effects are a future need outside the scope of this Gravel Guidance document. Nevertheless, it is recommended that individual gravel extraction operations be judged from a perspective that includes their potential adverse cumulative impacts (Kondolf 1997, 1998a; see also Council on Environmental Quality, Office of Federal Activities 1997 and U.S. EPA 1999 for general cumulative impact guidance). It is recommended that this be a part of any gravel extraction management plan.

11. **NOAA Fisheries recommends that an integrated environmental assessment, management, and monitoring program be a part of any gravel extraction operation, and encouraged at Federal, state, and local levels.** Assessment is used to predict possible environmental impacts. Management is used to implement plans to prevent, minimize, and mitigate negative impacts. Monitoring is used to determine if the assessments were correct, to detect environmental changes, and to support management decisions. It is important that mitigation be based on replacing equivalent habitat values and functions, as per the COE's Regulatory Guidance Letter on compensatory mitigation. It is recommended that a mitigation and restoration strategy be included in any management program, and that a mechanism for correcting problems identified via monitoring be written into the permit, as monitoring is not worthwhile unless there is a mechanism to address problems that are identified as a result of the monitoring program.

12. **NOAA Fisheries recommends that mitigation and restoration be an integral part of the management of gravel extraction projects.** In terms of National Environmental Policy Act (NEPA) regulations, mitigation includes: (1) Avoidance of direct or indirect impacts or losses; (2) Minimization of the extent or magnitude of the action; (3) Repair, rehabilitation or restoration of integrity and function; (4) Reduction or elimination of impacts by preservation and maintenance; and (5) Compensation by replacement or substitution of the resource or environment. Thus, restoration is a part of mitigation, and according to the preceding definitions, it is recommended that the aim of restoration be to restore the biotic integrity of a riverine ecosystem, not just to repair the damaged abiotic components. An overview of river and stream restoration can be found in Gore et al. (1995). Koski (1992) states that the concept of stream habitat restoration as applied to anadromous fishes is based on the premise that fish production increases when those environmental factors that limit production are alleviated. Thus, an analysis of those "limiting factors" is critical to the restoration process. Koski (1992) further states that effective stream habitat restoration must be holistic in scope, and approached through a three-step process:

    1. First, a program of watershed management and restoration must be applied to the watershed to ensure that all major environmental impacts affecting the entire stream ecosystem are addressed (i.e., cumulative impacts). Obviously, an individual gravel extraction project is not expected to restore an entire watershed suffering from cumulative effects for which it was not responsible. Rather, needed mitigation and restoration activities in a riverine system should focus on direct and indirect project effects and must be designed within the context of overall watershed management.

2. Next, restore the physical structure of the channel, instream habitats, and riparian zones (e.g., stabilize stream banks through replanting of riparian vegetation, conserve spawning gravel, and replace large woody debris). This would reestablish the ecological carrying capacity of the habitat, allowing fish production to increase.

3. Finally, the fish themselves should be managed to ensure that there are sufficient spawning populations for maximizing the restored carrying capacity of the habitat.

For further guidance on mitigation, refer to The USACE Regulatory Guidance Letter (USACE, 2002) and the joint guidance on the Use of In-Lieu-Fee Arrangements for Compensatory Mitigation Under Section 404 of the Clean Water Act and Section 10 of the Rivers and Harbors Act (65FR 66913, November 7, 2000).

13. **NOAA Fisheries recommends that gravel extraction projects proposed as stream restoration activities be regarded with caution.** Resource management agencies acknowledge that, under the right circumstances, some gravel extraction projects, whether commercial or performed by the agencies themselves, may offer important opportunities for anadromous fish habitat enhancement. That is, gravel removal itself can be used beneficially as a tool for habitat creation, restoration, or rehabilitation (OWRRI 1995). While it is tempting to promote gravel extraction as a means to enhance or restore stream habitat, the underlying objective of the Guidance document is to prevent adverse impacts caused by commercial gravel extraction operations. Therefore, it is recommended that gravel extraction for habitat enhancement purposes done in conjunction with commercial gravel operations not take precedence, and not be a substitute for, habitat protection.

NOAA Fisheries recommends that either a mitigation fund, with contributions paid by the operators, or royalties from gravel extraction be used to fund the mitigation and restoration programs as well as for effectiveness monitoring.

V. OPTIMUM MANAGEMENT OF GRAVEL EXTRACTION OPERATIONS

This section outlines a basic management scenario for gravel extraction operations, with the goal of minimizing impacts to anadromous fishes and their habitats. It is organized around the three program elements outlined in recommendation 12. This general framework is intended only as an introductory guide for creating a more comprehensive assessment, management and monitoring program. Other examples can be found in the literature (e.g., Collins and Dunne 1990; OWRRI 1995).

Before implementing Phase I, the operators should submit plans to the appropriate Federal, State and local agencies outlining their proposed project, including locations, methods, timing, duration, proposed extraction volumes, etc. The operators should also check with their NOAA Fisheries Regional Offices for any region specific procedures and guidelines.

Phase I. Prior to extraction, establish existing biological and physical conditions; evaluate possible environmental impacts, and describe ways in which adverse environmental impacts are to be prevented or minimized, with the goal of achieving and maintaining the natural ecological functions of the habitat. Using a combination of best available technologies and methods, assess the following:

- Characterize and identify species distributions, abundances, and life stages;
- Identify habitat requirements and determine limiting environmental factors of the anadromous fish populations (see Koski 1992);
- Calculate sediment budgets and hydraulic flow rates, taking into consideration such periodic natural events as floods (Meador and Layher 1998), and the episodic nature of watershed hydrology;
- Predict possible changes in water quality, channel morphology, and potential adverse cumulative impacts;
- Propose a mitigation and restoration strategy based on first preventing impacts, minimizing unavoidable impacts, and mitigating for all immediate and cumulative impacts.

Phase II. Monitor permitted operations and verify environmental safeguards. Extraction rates and volumes should be closely monitored. Impacts to the riverbed, banks and bars upstream and downstream of the project should be documented using benchmarked channel cross-sections and aerial photographs taken at regular intervals. Species distributions and abundances should be surveyed regularly. Water quality should be monitored. Mitigation and restoration should be an ongoing process (see Recommendation No. 12, above), with continual monitoring for effectiveness. Also, NOAA Fisheries recommends that permits should have a maximum 5 year limit and be subject to annual review and revision to protect anadromous fish and their habitats (e.g., one element of the annual review should determine whether fishery management objectives are being met). A third party should be responsible for carrying out monitoring activities, and for reporting to the permitting agency, the operator, and the appropriate natural resource agencies and other stakeholders.

Phase III. Establish and implement a long-term monitoring and restoration program. This should continue Phase II objectives after completion of the project. A universal, prototype long-term monitoring strategy for watershed and stream restoration can be found in Bryant (1995); see also the various papers by Kondolf and others (e.g., Kondolf and Larson 1995; Kondolf and Micheli 1995; Kondolf 1998b). In addition, see Beechie and Bolton (1999), who discuss approaches to restoring salmonid habitat-forming processes in Pacific Northwest watersheds, and Roni et al. (2002), who review stream restoration techniques and devise a hierarchical strategy for prioritizing restoration in these watersheds.

Without restoration, stream recovery from gravel mining can take decades (Kanehl and Lyons 1992). However, reliance on restoration should be put into proper perspective. It is important to acknowledge that there are significant gaps in our understanding of the methodology and effectiveness of restoration of streams and anadromous fish habitat affected by gravel extraction activities. Overall, restoration as a science is relatively young and experimental, and the processes and mechanisms are poorly understood. Little is known about the functional value, stability and resiliency of many so-called “restored” habitats. To date, existing regulations or plans pertaining to the mitigation and restoration of gravel extraction sites have been simplistic or vague. As an example: gravel extraction in California is regulated under the concept of “reclamation,” which is derived from open-pit surface mining, such as large coal mines. Kondolf (1993, 1994b) states the concept of reclamation, as applied to open-pit mines, assumes that the environmental impacts are confined to the site; therefore, site treatment is considered in isolation from changes in the surrounding terrain.

Because reclamation does not occur until after the cessation of extraction, Kondolf (1993, 1994b) suggests that this definition treats the site as an essentially static feature of the landscape. Kondolf (1993, 1994b) argues that, while these assumptions may work for extraction operations located in inactive stream or river terraces, active channels and floodplain are dynamic environments, where disturbances can spread rapidly upstream and downstream from the site during and after the time of operation. The stream or river will irrevocably readjust its profile during subsequent high flows, eradicating the gravel pits and giving the illusion that extraction has had no impact on the channel. Kondolf (1993, 1994b) claims that a survey of bed elevations will show a net lowering of the bed, which reflects the more even distribution of downcutting (erosion) along the length of the channel. Even if the channel profile were to recover after completion of the project due to an influx of fresh sediment from upstream, habitat may have been lost in the meantime. Thus, it may not be possible to disturb one site in isolation from the rest of the ecosystem, or confine the disturbance to a single, detached location, and then subsequently reclaim or reverse the impacts (Brown et al 1998). Kondolf (1993, 1994b) concludes that reclamation can be applied to gravel pits in terrace deposits above the water table, but the reclamation concept is not workable for regulating instream gravel extraction. Similarly, in regards to instream gravel mining, Brown et al. (1998) conclude that, “total restoration of severely affected streams would probably be impossible.”

Moreover, Kondolf (1998a) reminds us that:

> The effects of instream gravel mining may not be obvious immediately because active sediment transport is required for the effects (e.g. incision, instability) to propagate upstream and downstream. Given that geomorphically-effective sediment transport events are

> infrequent on many rivers, there may be a lag of several or many years before the effects of instream gravel mining are evident and propagate along the channel. Thus, gravel mines may operate for years without apparent effects upstream or downstream, only to have the geomorphic effects manifest years later during high flows. Similarly, rivers are often said to have 'long memories', meaning that the channel adjustments to instream extraction or comparable perturbations may persist long after the activity itself has ceased.

For all of these reasons, it is important to heed Murphy's (1995) assertion that:

> The best form of restoration is habitat protection. There is no guarantee that restoration efforts will succeed, and the cost of restoration is much greater than the cost of habitat protection. The most prudent approach is to minimize the risk to habitat by ensuring adequate habitat protection.

In light of the dynamic, unpredictable, and episodic nature of stream hydrology and sediment transport, NOAA Fisheries cautions against relying on restoration, and emphasizes instead the importance of preventing and avoiding any adverse impacts to anadromous fish and their habitats.

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APPENDIX 1

SUMMARIES OF MAJOR STATUTES

The following summaries of the major statutes mentioned in this Gravel Guidance document, with the exception of the River and Harbor Act of 1899, were obtained from Buck (1995)[1].

Clean Water Act

The Clean Water Act (CWA) (33 *U.S.C.* 1251-1387) is a very broad statute with the goal of maintaining and restoring waters of the United States. The CWA authorizes water quality and pollution research, provides grants for sewage treatment facilities, sets pollution discharge and water quality standards, addresses oil and hazardous substances liability, and establishes permit programs for water quality, point source pollutant discharges, ocean pollution discharges, and dredging or filling of wetlands. The intent of the CWA Section 404 program and its 404(b)(1) Guidelines is to prevent destruction of aquatic ecosystems including wetlands, unless the action will not individually or cumulatively adversely affect the ecosystem. National Marine Fisheries Service (NOAA Fisheries) can provides comments to the U.S. Army Corps of Engineers as to the impacts to living marine resources of proposed activities and recommends methods for avoiding such impacts.

If NOAA Fisheries determines that a proposed action will result in “substantial and unacceptable adverse impacts on aquatic resources of national importance,” the Assistant Secretary for Oceans and Atmosphere may request that the decision be reviewed at a higher level in the USACE. A 404(q) elevation pauses the permit process for about two months while the two departments exchange information to address concerns about the proposed project. While outright permit denials are rare, there are often modifications to the project proposal resulting in a less harmful action.

Endangered Species Act

The purpose of the 1973 Endangered Species Act (ESA) (16 *U.S.C.* 1531-1543) is to provide a means whereby the ecosystems upon which endangered or threatened species depend may be conserved, and to provide a program for the conservation of such endangered and threatened species. If a Federal action may effect ESA-listed species, the action agency must initiate consultation with NOAA Fisheries under section 7. Other pertinent sections include section 9 (direct take) and section 10 (All Federal departments and agencies shall seek to conserve endangered and threatened species and shall utilize their authorities in furtherance of the purposes of the ESA.

[1]Buck, E.H. 1995. Summaries of major laws implemented by the National Marine Fisheries Service. CRS Report for Congress. Congressional Research Service, Library of Congress, March 24, 1995.

Fish and Wildlife Coordination Act

The Fish and Wildlife Coordination Act (16 *U.S.C.* 661-666c) requires that wildlife, including fish, receive equal consideration and be coordinated with other aspects of water resource development. This is accomplished by requiring consultation with the FWS, NOAA Fisheries and appropriate state agencies, whenever any body of water is proposed to be modified in any way and a Federal permit or license is required. These agencies determine the possible harm to fish and wildlife resources, the measures needed to both prevent the damage to and loss of these resources, and the measures needed to develop and improve the resources, in connection with water resource development. NOAA Fisheries submits comments to Federal licensing and permitting agencies on the potential harm to living marine resources caused by the proposed water development project, and recommendations to prevent harm.

Magnuson Fishery Conservation and Management Act

The Magnuson-Stevens Fishery Conservation and Management Act, first passed in 1976 and most recently amended in 1996, is the primary legislation governing marine fisheries. This legislation established eight regional Fishery Management Councils to manage fishery resources in the Exclusive Economic Zone under Fishery Management Plans (FMPs) for Federally managed fisheries. Plans may include one or several species and are designed to achieve specified management goals for a fishery.

The 1996 re-authorization of the Magnuson Act included Essential Fish Habitat (EFH) provisions were added in 1996. The act states: "One of the greatest long-term threats to the viability of commercial and recreational fisheries is the continuing loss of marine, estuarine, and other aquatic habitats. Habitat considerations should receive increased attention for the conservation and management of fishery resources of the United States" (16 U.S.C. 1801 (A)(9)). The definition of EFH in the legislation covers: “those waters and substrate necessary to fish for spawning, breeding, feeding, or growth to maturity.” The legislation mandates that NOAA Fisheries and the Councils implement a process for conserving and protecting EFH. Key features of this process are:

1. *Designate EFH.* Councils are required to describe and identify EFH for each life stage of the species included in their FMPs.
2. *Minimize to the extent practicable the adverse effects of fishing on EFH.* Councils must assess fishing impacts to EFH, taking Habitat Areas of Particular Concern (HAPCs) into special consideration (i.e., habitat types that are especially sensitive, ecologically important, or rare), and minimize the impacts of fishing on EFH to the extent practicable.
3. *Consult on potential fishing and non-fishing impacts to EFH.* NOAA Fisheries and the Councils are required to comment on activities proposed by Federal action agencies (e.g., Army Corps of Engineers, Federal Energy Regulatory Commission, Department of the Navy) that may adversely impact areas designated as EFH.
4. *Further review of decisions inconsistent with NMFS or Council Recommendations*. If a Federal agency decision is inconsistent with a NOAA Fisheries conservation recommendation, the

Assistant Administrator for Fisheries may request a meeting with the head of the Federal action agency to review and discuss the issue.

National Environmental Policy Act

The National Environmental Policy Act (NEPA) (42 *U.S.C.* 4321-4347) requires Federal agencies to analyze the potential effects of a proposed Federal action which would significantly affect the human environment. It specifically requires agencies to use a systematic, interdisciplinary approach in planning and decision-making, to insure that presently unquantified environmental values may be given appropriate consideration, and to provide detailed statements on the environmental impacts of proposed actions including: (1) Any adverse impacts; (2) Alternatives to the proposed action; and (3) The relationship between short-term uses and long-term productivity. The agencies use the results of this analysis in decision making. Alternatives analysis allows other options to be considered. NOAA Fisheries plays a significant role in the implementation of NEPA through its consultative functions relating to conservation of marine resource habitats.

Rivers and Harbors Act of 1899

The Rivers and Harbors Act of 1899, Section 10 (33 *U.S.C.* 403) authorizes the USACE to regulate activities that affect waters of the United States. These activities include construction of wharves, piers, jetties; and excavating or altering stream channels of navigable waters. NOAA Fisheries may comment on proposed activities (usually via the FWCA), and the CWA 404(q) elevation process (see Clean Water Act, above) is available to NOAA Fisheries under the Rivers and Harbors Act.