Chapter 6
Retrofitting Existing Projects

6-1. General

The addition of hydropower facilities at the existing Corps of Engineers projects must not jeopardize the public interest relative to water control management for flood control, navigation, water supply, water quality, recreation and other project proposes. In addition, those aspects of the design that could affect the safety of the project must be consistent with Corps standards as to requirements of this manual and all referenced manuals and regulations. To ensure compliance with this policy when development is by non-federal licenses, the Corps of Engineers will review and approve the proposed detailed design analysis and plans and specifications for those hydraulic, structural and mechanical features that could affect the integrity and safety of the total project. Major items of concern, but not necessarily limited to, are discussed as follows:

6-2. Hydraulic Design Considerations

a. Proposals. Proposals to add hydropower facilities at Corps of Engineers projects must thoroughly address the hydraulic design details and the overall functional capability. Items that must be addressed include the following.

(1) Streamlining of entrance to power penstock from flood control conduit must be addressed.

(2) Streamlining to preclude cavitation in flood control conduit at junctions with penstock or gate slots must be addressed.

(3) Positive and negative pressure surges due to powerhouse load rejections, load acceptance, and unit runaway is another important item to address.

(4) Reassessment of water quality provisions to include size and location of multi-level intakes and compatibility of powerhouse release requirements with water quality requirements is an important item.

(5) Means of dewatering power facilities without interrupting water quality and/or flood control releases must be addressed. However, some powerhouses with long penstocks, or those with only gates or valves immediately upstream of the powerplant need not be dewatered except under emergency conditions. This procedure can be followed only if it does not impact upon dam safety of flood control regulations. This type of penstock can be inspected using divers or remotely operated cameras.

(6) Effects of adding trashracks in the existing intake if required for equipment protection must be addressed.

b. Submittals. Submittals proposing inclusion or addition of hydropower combined with water quality and or flood control facilities at Corps of Engineers projects must include a hydraulic design analysis covering all operating and emergency conditions. Presentations need to address all items discussed above. Information on energy and pressure grade lines throughout the hydraulic passages covering maximum and minimum conditions with local pressure drops at such places as bends, junctions, transitions, gate slots, etc., is necessary. The presentations must include an analysis of the effects of a powerhouse load rejection. The degree of detail is to be sufficient for the study stage being presented, although at final design stage. a transient analysis utilizing state-of-the-art computer programs must be performed and reviewed by a Design Center. The requirements apply to proposals from others (to be accomplished at their expense) as well as to in-house proposals.

c. Penstocks. The existing regulating outlet conduits offer an available connection between the reservoir and potential hydropower facilities. Regulating outlet conduits ar flood control or other non-power projects are usually designed for non-pressurized (open channel) flow conditions. for the most part, these conduits are of reinforced concrete designed to withstand external rock or embankment loads and external hydrostatic pressures. Once hydropower facility is connected, the primary structural concern is that an existing regulating outlet conduit becomes a power penstock subject to internal pressures equal to full pool plus any transient pressures due to water manner effects. Submittals proposing inclusion or addition of facilities at Corps of Engineers projects must include structural and geotechnical analysis covering all operating and emergency conditions. Presentations need to address all items covered in this guidance. The degree of detail presented should be sufficient for the study stage being presented. This applies to proposals from others (to be accomplished at their expense) as well as to in-house proposals. The following paragraphs present acceptable design criteria for converting regulating outlet conduits to power penstock (downstream control).

6-3. Geotechnical Considerations

Original geologic conditions upon which project design was based, and upon which cut and cover or lines or unlined tunnels were constructed, must be known so that safety and original design benefits are not reduced. Water must not be allowed to escape into the dam abutments from pressurized tunnels to cause slope stability problems or groundwater changes that might affect the dam. An investigation of geologic conditions relative to the design proposed for a pressurized tunnel must be made. Existing lined tunnels may conceal voids, shear zones, rock of low deformation modulus, etc. When modifying existing lined tunnels, design shall recognize and provide for the above possibilities, just as it would for unlined tunnels containing geologic weaknesses. Full length grouting behind linings or other measures may be necessary. If an existing tunnel is acting as a drainage feature in an abutment, intentionally or unintentionally, the possibility of groundwater pressure changes occurring after modification should be evaluated. The function and many of the details of construction and erection for an integrally embedded steel liner are similar to a free-standing penstock; however, the loading conditions are different. The steel lining, concrete encasement, and if present, the surrounding rock act together to resist the pressures. EM 1110-2-2901 outlines in detail the loading conditions and allowable stresses for a conduit under embankments or rock. In both instances, external pressures must be accounted fro as well as the internal pressures.

6-4. Tunnels in Rock Abutments

An existing outlet tunnel (unlined or lined with other than steel) should be investigated to determine to what extent the tunnel should be lined with steel plate to prevent leakage that could present a danger to the dam or abutment. The extent of steel liner plate should be sufficient to prevent leakage along rock fissures or joints that intercept the dam or downstream of the impervious zone. An existing tunnel liner must be investigated for internal pressures that will occur once the hydropower facility is installed. In regions of an existing regulating outlet tunnel liner where the rock cover is insufficient to offset internal pressures, or where geologic weaknesses exist, a new liner may be required fro structural reasons. A steel linerplate could be grouted in place and designed as composite with an existing concrete liner, provided the existing liner reinforcement is adequate for all loads (see EM 1110-2-2901). If the tunnel is unlined of if the existing liner reinforcement is inadequate, a separate free-standing penstock or new reinforced concrete liner with composite steel liner plate should be provided.

6-5. Cut and Cover Conduits

a. General. In its existing non-pressurized condition, these conduits are generally reinforced concrete structures without steel plate liners. To prevent leakage that would endanger the embankment dam, a steel lining is required from the upstream face of the impervious zone to the powerhouse. A reinforced concrete liner composite steel liner plate, or a free-standing penstock, may be required to structurally accommodate the internal full pool pressures resulting from downstream control plus additional pressures due to water hammer effects.

b. Circular conduits. A steel liner grouted to be integral with the existing concrete liner may be used provided the requirements of EM 1110-2-2901 are met. If the existing concrete reinforcement does not meet the above requirements, a free-standing type penstock or new reinforced concrete liner with composite steel liner plate should be provided.

c. Non-circular conduits. A free-standing penstock, erected within and independent of the existing regulating outlet conduit, should be provided.

6-6. Free-Standing Penstocks Within Conduits

Free-standing penstocks constructed within an existing conduit shall be designed in accordance with paragraph 4-16, penstocks and surge tanks. Plates and joints should be designed for full pressure due to static head plus water hammer as well as any negative pressures developed by hydraulic transients. All joints should be welded except for the connection of the penstock to the spiral case, which is normally a flexible type. Free-standing penstocks should be constructed so as to permit any leakage to drain to tailwater without pressurizing the surrounding regulating outlet conduit. Careful attention should be given to anchorage of the penstock against longitudinal thrust.

a. Gates and valves. The addition of hydropower facilities must include provisions for isolating the powerplant so as not to interfere with the project original purpose. When the existing flood control conduit is modified for penstock use, a closure device such as a butterfly or spherical valve or a gate must be provided at the powerhouse end of the penstock for shutoff of flow

during emergency closure or during normal maintenance of the equipment.

(1) The closure device should be designed for maximum penstock head including water hammer and hydrostatically tested for 150 percent of the maximum design conditions. The valve operator must be capable of closing the device in from 2 to 5 minutes as practical for its size. The closure capability must be achievable without outside power. Thus, an energy storage device such as an accumulator or counterweight is required.

(2) The closure of the normal water passage at the downstream end for diverting flow to the turbine is subject to the specific project layout. Gates or valves used for this purpose must be designed for the maximum water pressure, including water hammer, and subject to hydrostatic testing in place.

b. Vents. When the existing flood control facilities are utilized for hydropower purposes, all the existing components require careful analyzing and investigation for any adverse cavitation or structural effects. One such item subject to structural loading greater than originally thorough analysis of the effects such changes would have on the system when used in the original operation mode for the project purpose. During powerhouse operation the vents are subject to full hydrostatic pressure including water hammer, and therefore structural adequacy should be thoroughly investigated for this condition as well as the seismic condition.

c. Bifurcation. In most instances, the utilization of the existing regulating conduit requires diverting the water flow from the conduit to the power producing facilities. The method of accomplishing this objective requires a bifurcation or diverting box depending of the specific site conditions. The method chosen must be thoroughly analyzed for potential cavitation or structural effects and may require model testing to verify the design. For further structural requirements, see paragraph 4-16*e*.