

TECHNIQUES FOR MINIMIZING AND MONITORING THE IMPACT OF PIPELINE CONSTRUCTION ON COASTAL STREAMS¹

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Abstract: This paper describes specific measures recently employed for protection of riparian resources during construction of an oil and gas pipeline that crossed coastal reaches of 23 perennial and intermittent streams between Point Conception and Gaviota in Santa Barbara County, California. Flumes were constructed to maintain stream flow; anchored straw bales and silt fences were used to filter sediment in the streams; water bars, incorporated straw mulch, anchored jute fabric, and trench plugs were installed to minimize soil loss on slopes; jute and synthetic fabrics were used to stabilize stream banks; construction-related removal of vegetation was minimized through site-specific project modifications agreed to prior to construction; and impacts on sensitive plant species were reduced by transplanting or by salvaging and replanting after construction. Construction at stream crossings was limited by permit to the summer period of normally low streamflows and was required to avoid the breeding season of sensitive riparian-dependent bird species. Restoration of native woody vegetation was encouraged through a number of approaches emphasizing use of material native to the individual watersheds. Many of the more successful approaches employed in this project resulted from refinements to original plans made in the field by representatives of the applicant, construction contractors, consultants to the applicant, environmental monitors, and representatives of Santa Barbara County.

The Point Arguello pipeline was recently constructed by Chevron U.S.A. Inc. to convey outer-continental-shelf (OCS) oil and gas from offshore platforms near Point Conception to a processing facility at Gaviota in Santa Barbara County, California. Construction of the onshore portion of the pipeline, which parallels the coastline, involved crossing 23 perennial and intermittent streams along its 16-mile onshore alignment (Figure 1). Distance from the ocean along the alignment ranges from about 1 mile on the west to a few hundred feet at Canada Agua Caliente and Canada de Alegria. The project involved burial of a 24-inch diameter oil pipeline and a 20-inch gas pipeline within a single trench. Burial depth was a minimum of 36 inches to top of pipe, with greater depths required at certain stream crossings in order to protect the pipes from scour during floods. Con-

struction activities were confined to a 100-foot maximum right-of-way (ROW). The construction corridor was narrowed to less than 100 feet (from 20 to 80 feet) at stream crossings where feasible.

From a landfall about 1.5 miles north of Point Conception, the pipeline crosses coastal terraces and low hills vegetated primarily by annual grassland dominated by a variety of introduced grasses. Coastal sage scrub, dominated by coastal sagebrush (*Artemisia californica*) or purple sage (*Salvia leucophylla*), occurs locally, especially on hillsides leading into drainages. The drainages are typically well-incised into the terraces, with the streambeds generally lying 40 feet or more below the terrace elevation. The stream corridors typically are vegetated by riparian forests or woodlands. These are dominated exclusively by arroyo willow (*Salix lasiolepis*) along the drier watercourses. In addition to arroyo willow, larger streams may support occasional red willow (*Salix laevigata*), black cottonwood (*Populus trichocarpa*), western sycamore (*Platanus racemosa*), and box elder (*Ater negundo* subsp. *californicum*). White alder (*Alnus rhombifolia*) occurs in the vicinity of the ROW and is confined to areas of perennial flow. Coast live oak (*Quercus agrifolia*), toyon (*Heteromeles arbutifolia*) and elderberry (*Sambucus mexicana*) commonly occur in and adjacent to the riparian zone, but are not exclusively riparian species in this region. Steep hillsides, leading into the streambeds, are occasionally dominated by nearly pure stands of holly-leaf cherry (*Prunus ilicifolia*), that may be relicts of an earlier occurrence of chaparral.

From west to east, the pipeline corridor crosses the Bixby Ranch, the Hollister Ranch, Gaviota State Park and smaller private landholdings near its eastern terminus. Livestock grazing is the predominant land use along the pipeline ROW, except in Gaviota State Park. The Hollister Ranch is subdivided into 100-acre parcels, most of which contain residences.

The entire pipeline alignment lies in the Coastal Zone and most of the riparian habitats it crosses are designated environmentally sensitive habitat areas (ESHA) in the Santa Barbara County local coastal plan (LCP) (Santa Barbara County 1982). Among other things, the ESHA designation recognizes the importance of these

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Figure 1 — Project location near Point Conception

corridors to the overall landscape. They provide food, escape cover, water sources, and movement corridors for a variety of wildlife that use the surrounding upland habitats.

A number of sensitive aquatic and avian species were located in these habitats, especially in the larger, less disturbed streams. Sensitive aquatic species occurring in streams crossed by the pipeline alignment

included tidewater goby (*Eucyclogobius newberryi*), California red-legged frog (*Rana aurora draytonii*), and southwestern pond turtle (*Clemmys marmorata pallida*), and reported runs of steelhead trout (*Salmo gairdneri*). The tidewater goby, red-legged frog and southwestern pond turtle are category 2 candidates for federal listing as threatened or endangered. (A category 2 candidate species is one that U. S. Fish and Wildlife Service [USFWS] believes may be appropriate for listing but for which additional information is required.) Preservation, maintenance and improvement of steelhead trout habitat is of high management interest to both California Department of Fish and Game (CDFG) and USFWS. Site-specific information on the stream crossings as well as additional general information on the project region is provided in Mulroy and others (1984).

Environmental Protection Measures

Specific environmental protection measures were developed through the environmental review process and incorporated into the project. These include measures to maintain stream flow, to control sediment, to stabilize stream banks, to minimize construction-related removal of vegetation, to preserve rare plants, to protect sensitive wildlife and aquatic species, and to restore the native vegetation. Some of these measures were originally developed by the applicant and outlined in the original project description; others were recommended by the EIS/EIR preparers. The EIS/EIR review was directed by a joint review panel of permitting agencies, led by the U.S. Minerals Management Service and the County of Santa Barbara. Many of the mitigation measures were originally described in a restoration, erosion control, and revegetation plan for the onshore work area (Chevron 1986) prepared by Chevron after the EIS/EIR as part of their final development plan (FDP) as required by Santa Barbara County permit conditions. This plan was developed in consultation with Santa Barbara County and refinements were made in response to comments from the Santa Barbara County Resource Management Department, Energy Division.

Further developments and refinements of the approved plans were made in the field during their implementation. This was generally done with the input of engineers, environmental staff, and consultants employed by Chevron, and input from environmental staff, monitors, and consultants representing Santa Barbara County. Environmental monitoring to ensure compliance with permit conditions was done according to a detailed environmental quality assurance program (EQAP) employing an onsite environmental coordinator (OEC), general environmental monitors, and resource specialists such as biologists.

Maintenance of Stream Flow

Permit conditions (Santa Barbara County 1984) required that construction activity be confined to low-flow periods, basically the summer and early fall months, and that the existing flow be maintained across the construction area at all times. Construction during the low-flow period helps minimize impacts on water quality; maintenance of low flows was judged essential to maintain downstream populations of aquatic biota, including several sensitive vertebrate species.

Prior to construction at a given stream crossing, sediment traps were installed as described in the next section, and vegetation was removed from the construction right-of-way (ROW). The initial work involved crews using chain saws, who were able to minimize disturbance to vegetation outside the ROW (e.g., by directional felling of trees). The ROW was generally perpendicular to the stream course and a flume was installed to convey water across the ROW. The flume consisted of a large pipe along the bottom of the streambed extending from a short distance upstream of the ROW to a short distance downstream from the ROW. Project specifications called for construction of a temporary dam, consisting of straw bales and plastic, at the upstream end of the ROW to direct water into the pipe. Generally, it was necessary to have the pipe flush with the stream bottom and to have the opening surrounded by sandbags to minimize leakage. At the downstream end, simple energy dissipation structures were installed to prevent erosion caused by the concentrated flow exiting the pipe.

Following sediment trap installation, vegetation removal, and flume installation, pipeline trenching was conducted with backhoes under the flume, which stayed in place for the duration of construction activities at a given stream crossing.

Sediment Control

Conveying the stream water across the construction area in a flume minimized the construction-related sediment that could have fallen into the water. At the downstream side of the ROW, silt traps were installed prior to construction. These traps typically consisted of a combination of two staggered rows of straw bales anchored with rebar and a curtain of commercial silt fence fabric keyed into the stream bottom at the downstream side of the straw bales. These sediment traps served as the primary means of sediment control after the trench had been backfilled and the flume removed. Accumulated sediment was removed from the upstream side of the traps by hand and disposed of away from the creek. It was found that the silt fence fabric by itself was ineffective. The fabric rapidly became clogged with sediment, causing stream flow to back up until the water began

to flow around, over, or under the fence. The silt fences required regular monitoring and maintenance. The staggered straw bales were relatively effective and simple to maintain, provided that the flow was not too great.

At higher flows, the sediment traps acted like a dam, retarding the flow until the water backed up and cut around the sides of the bales, eroding the banks. Sediment would drop out of the water behind the dam. Eventually this problem was solved by installing one or more L-shaped overflow pipes that would take the cleaner surface water from behind the dam and convey it under the hay bales and silt fence.

The sediment traps were left in place until after the first rainstorms following construction. Prior to their removal, the accumulated sediment was removed and disposed of away from the creek bed.

Accumulation of water in the trench created a problem at several crossings. When pumped from the trench, the discharged water tended to be sediment-laden, and the concentrated pump discharge caused local scouring of the streambed. In cases of very low discharge rates, the sediment was controlled by silt traps such as those described above. At certain streams, groundwater accumulation necessitated pump discharge rates that exceeded the capacity of the sediment control system. In these cases, one or two swimming-pool-sized "baker" tanks were used to receive discharge and to act as sediment traps by allowing sediment to settle out of the relatively calm water. Sediment-free water was then siphoned from the top of these tanks and returned to the stream bed. An alternative way of handling the higher rates of accumulated groundwater was to discharge it through sprinklers to upland habitats draining into the creek.

At one crossing, buried marsh sediments yielding abundant groundwater were encountered during trenching. This water was laden with hydrogen sulfide and fine sediment. Observation at other stream crossings indicated that the material was toxic to invertebrates. To maintain workable conditions in the trench, several shallow dewatering wells were installed and cased with perforated PVC plastic drain pipes. The discharge from these wells was too copious for the above-described systems to handle. The short distance of stream between the construction site and the shore was considered extremely sensitive to impact because it contained three aquatic species that are candidates for federal listing (tidewater goby, red-legged frog, and southwestern pond turtle) and had very little flow at the time of construction. To protect the stream and its biota, the water was piped to the nearby beach and discharged onto the sand, where filtering by the sand and dilution in the ocean water would minimize adverse ecological effects.

Stream-Bank Stabilization

After completion of welding and testing, the trench was backfilled, and the crossing was recontoured to its approximate preconstruction configuration. Original specifications called for armoring stream banks below the normal high water level with a three dimensional nylon "geotextile fabric." This armoring was intended to protect the banks and cause sediment to accumulate in the mesh, where it would ultimately be stabilized by vegetation.

In practice, the fabric proved to be relatively difficult to install, especially where it had to be keyed in to the stream bottom. There were concerns about its longevity, the aesthetic impact of exposed portions of the mesh, and the possibility of its being washed out by floodwater and causing downstream problems (e.g., clogging culverts). There was also a concern that the mesh would cause girdling of roots of willows and other woody plants expected to colonize the banks. As a result, this material was removed from several drainages. Where it was left in place, the material functioned adequately in low-flow situations where the drainage was broad with little gradient. However, these situations are the least prone to erosion. Elsewhere, it was heavily damaged by seasonal runoff or by livestock. Based upon this experience, we would not recommend the use of this material in a similar environment, especially in areas frequented by cattle.

Water bars (earthen berms graded across the ROW at a slight angle to the topographic contour) were installed at intervals along the steeper slopes to divert runoff from the ROW into adjacent vegetated areas. The spacing between water bars depended upon the steepness of the slope. On the steepest slopes, they were installed at 25-foot intervals. These bars effectively prevented the concentration of runoff and consequent erosion along the ROW but did require periodic repairs after winter storms. Damage caused by livestock also required repair. Gullying occurred at the edge of the ROW if the berms were not continued a slight distance beyond the ROW into the adjacent vegetation.

Jute netting was installed on steep slopes above the high water mark. This fabric was intended to retard washing of the exposed soil and backfill from the ROW into the creek. It was also expected to facilitate the establishment of vegetation by trapping and holding seeds in place, as well as by holding the soil. Proper installation requires that the fabric be placed in intimate contact with the soil surface, otherwise it can be undermined by runoff and become ineffective. Damage caused by cattle was extensive. Where properly installed and undamaged by cattle, the jute appeared to be an effective erosion-control measure. Postconstruction revegetation on the jute-netted slopes has been relatively slow,

however, leading to speculation that some property of the jute might have been inhibitory to seed germination or establishment. We believe that this could as easily have been a function of the poor soils and steep slopes where the jute was used. We would recommend establishment of appropriate control areas in subsequent applications to resolve this issue and to better evaluate the effectiveness of the material.

Minimize Vegetation Removal

Santa Barbara County permit conditions required construction activities to be confined to a 100-foot wide ROW. Narrowing the ROW in sensitive habitats and avoiding sensitive resources such as trees wherever feasible was also required. Preconstruction walk-throughs were conducted by Chevron's consultant biologists and a Chevron inspector familiar with pipeline construction methods. Trees and large shrubs that would unavoidably be removed by construction were enumerated by species for the purpose of developing site-specific replanting specifications. In the process, possibilities for minimizing impacts were discussed, and sensitive vegetation was identified, prioritized, and flagged for avoidance. Later, trees were protected by surrounding them with heavy lath and wire snow fencing. Because we attempted to err on the side of saving trees, we identified and flagged the maximum number of plants that could possibly be avoided by construction, using optimistic assumptions.

It was later determined that removal of some marked trees was unavoidable, and these were unfenced after notification of the on-site environmental coordinator.

The snow fence proved to be very effective both in designating trees or resources to be avoided and in preventing the plants from being buried by spoil or damaged by heavy equipment operating in their vicinities.

Preserve Rare Plants

During preproject walk-throughs, seven local populations of Hoffmann's nightshade (*Solanum xanli* var. *Hoffmannii*), a California Native Plant Society List 4 species endemic to coastal Santa Barbara County, were located. Hoffmann's nightshade is a sprawling subshrub that clammers through other plants and roots at the nodes. Its characteristics led us to believe that it could be successfully transplanted (Mulroy and others 1984), and transplanting was incorporated into a permit condition by Santa Barbara County. The local populations were therefore flagged in the field for later salvage.

In early summer 1986, prior to construction, Hoffmann's nightshade plants were cut back, dug up, and

potted using native soil. The plants tended to fragment into rooted divisions during the excavation and were thus placed three divisions to a pot into 15-gallon plastic pots, each of which was color-coded according to source locality. Initially, the plants were maintained in the field near the ROW where they were protected by hog wire and shade cloth. Subsequently, they were moved to a local nursery where they were maintained outdoors. Normally a summer-dormant, drought-deciduous species, the plants had been nearly dormant when salvaged. However, many plants became active again and flowered in response to periodic watering during the summer months. There was a relatively high but unquantified survival of salvaged plants in the nursery. Replanting was accomplished during spring 1987 at their original localities in chicken-wire enclosures. Thirty-eight percent of the outplanted plants, including several plants from each local population, were surviving when last monitored (July 1988). These appear to be fully established.

Also undertaken were transplants of giant stream orchids (*Epipactis gigantea*) and scarlet monkey flower (*Mimulus cardinalis*). Both of these plants are widespread species but were singled out for this treatment because of their uncommonness in the project area. Both species occurred under the riparian canopy in relatively moist sandy soil adjacent to the bed of Canada del Cojo, one of the larger streams crossed by the ROW. The plants were dug up and immediately replanted in one of two preselected open sites outside of the ROW, one upstream and one downstream. Finding sites with the proper attributes that were not completely covered with vegetation was perhaps the most difficult aspect of this task. Excavating the root system of the monkeyflower proved to be impractical and the effort was abandoned after only a few were transplanted. To my knowledge, none of these survived. About a dozen of the stream orchid were moved, and some of these were surviving as of spring 1988.

Protect Sensitive Wildlife and Aquatic Species

The efforts to maintain stream flow and to protect in-stream water quality, described above, were directed at preserving local populations of the above-listed sensitive aquatic species. A permit requirement that construction be restricted to the low-flow season was directed at making these protection measures feasible. A related condition was placed on the project to delay construction until after the breeding period of a number of regionally rare and declining songbird species known or expected to breed in some of the habitats. The net effect of these two conditions was to leave a very narrow "window" for construction at stream crossings. Chevron approached this constraint by prioritizing stream crossing construction, having special crews work on the stream crossings.

These crossings were later tied in as the main construction spread traveled from west to east.

Survival of the tidewater goby populations was of special concern since, during most of the year, the fish are located in tiny lagoons near the stream mouths, where they would be vulnerable to local extirpation. Recolonization could only occur from other populations via the ocean and there had been no documented evidence that this could occur. For these reasons, sampling to monitor potentially affected goby populations was conducted before, during, and after construction as part of the Environmental Quality Assurance Program (EQAP). This sampling is described in a poster session at these meetings authored by Thompson, Dunlap, and Dungan.

Restore Native Vegetation

A detailed description of measures to revegetate the stream sides and adjacent slopes is beyond the scope of this paper. However, I would like to briefly mention a few things germane to the restoration of streambeds and riparian zones in particular. First, willow cuttings taken from trees immediately adjacent to the ROW were a rapid and inexpensive means of hastening the restoration of a tree cover over the stream. Generally, the use of dormant wood is preferred; however, cuttings taken in late spring survived. There was a high rate of survival of cuttings where soil moisture was adequate (i.e., near the streambed) even though they were not taken and planted until late spring.

Second, to hasten the stabilization of the streambed and recovery of marsh plants such as cattails in severely disturbed portions of the ROW, a simple method for salvage and replanting was developed for this project. This method involved digging individual clumps of cattails by hand out of the ROW prior to clearing, and storing them in plastic wading pools for later replanting. The wading pools can be located in shaded parts of the streambed adjacent to the ROW and watered periodically by construction monitors or inspectors. The ultimate success of this method remains untested because an errant bulldozer destroyed the plants and tub. Reestablishment of cattails from seed and rhizomes in the salvaged topsoil was rapid, however.

An example of a creative approach to seed collection was taken by one of the authors after a seed-collection contractor missed the brief period of seed availability of holly-leaf cherry or islay (*Prunus ilicifolia*), a large shrub or small tree forming coppices on steep slopes leading into several streams. A considerable amount of locally-collected seed was required for this species, which was one of the most important large shrubs along the ROW. One of the authors was able to collect nearly the entire required amount from the scats of coyotes which had fed

upon the cherry fruits extensively. The work of pack rats or wood rats (*Neotoma*) in collecting both scats and seed was taken advantage of in respect to this seed-collection attempt.

For most of its length, the ROW passed through active cattle ranches. Protection from grazing livestock was an important factor in the design of the revegetation program and was important in determining the success of the tree and shrub plantings. Box fencing was most effective in excluding cattle from the ROW at stream crossings, but they prevent up and downstream movement of cattle in the streambed, and for this reason landowners strenuously objected to their installation at most locations. Where properly installed, wing fences (fences constructed across the ROW and angling downslope for varying distances off the ROW) inhibited cattle from using the ROW for access to stream crossings and, in such areas, tree and shrub plantings fared substantially better than in areas in which fencing was absent or ineffective. In the latter cases, cattle tended to congregate in the ROW at the stream crossings and restoration plantings, and erosion control measures were heavily affected, requiring considerable maintenance and repair.

In upland habitats outside of the wing-fenced areas, a two-tiered exclusion system designed by one of the authors was used to exclude cattle, deer, and small mammals from shrub and Hoffman's nightshade plantings. The plantings were clustered within an area enclosed with standard three-strand barbed-wire fencing designed to exclude cattle. The individual plantings were protected from deer and small mammals by individual cages fabricated from chicken wire. These cages were about 30 inches in diameter and about 54 inches from top to bottom. The bottom 12 to 15 inches of the cage was buried below ground to provide protection from pocket gophers (*Thomomys bottae*).

The timing of revegetation activities is critical. Plans had been to complete pipeline construction and restoration activities prior to the onset of the November-to-April rainy season, in order to give the plantings and reseeded areas the maximum amount of time to become established before the summer drought. The project, unfortunately, fell behind schedule, and revegetation activities were not initiated until January 1987. Tree and shrub plantings were not accomplished until later that spring, when runoff had diminished to low levels and soils in the riparian areas away from the immediate channel had dried out. As a result, establishment of riparian trees and shrubs from cuttings and transplants was poor, except in areas within a few feet of the existing channel. Considerable reseeded of adjacent shrub-dominated upland habitats was required as well, necessitating additional custom collections of native seed from the immediate vicinity of the ROW.

Conclusions and Recommendations

The maintenance of stream flow during periods of low flow proved easier than did the removal and re-distribution of groundwater which accumulated in the pipeline trench. A trial-and-error approach was used to determine the best method for each drainage where this problem arose. For similar projects involving excavation through riparian zones, we would recommend that an estimation of groundwater quantity and quality and tactics for dealing with this excess water be determined prior to construction. As was the case with the Point Arguello pipeline project, appropriate site-specific solutions will have to be developed for this problem. In streams larger than those encountered in this project, reinjection of the groundwater may be feasible.

Use of geotextile fabric for stream bank stabilization did not appear appropriate and was discontinued. We believe that the revegetation of stream banks provides a superior degree of bank stabilization, without the potential drawbacks of the synthetic material.

Erosion was noted where water bars led into steep and poorly vegetated areas at the edge of the ROW. Otherwise, water bars were effective but required periodic repair of damage caused by storms or livestock.

Investigations of the effects of jute netting on plant growth are recommended. However, our experience suggests a possible inhibitory effect on revegetation.

Snow fencing was highly successful in protecting trees from burial and incidental damage by equipment operators.

A number of suggestions are made above for enhancing the reestablishment of riparian vegetation. An important step in much of the West is to restrict the access of livestock to recovering stream corridors. These areas are most vulnerable to damage from livestock during summer, when the animals tend to congregate in riparian areas and may do irreparable damage to young plants.

Finally, it is important that techniques to protect riparian zones from construction impacts be scrutinized and refined. Every attempt should be made to distinguish causal relationships from coincidences when the success or failure of mitigations is assessed. Ideally, this will involve rigorous experimental comparisons between treated areas and control areas.

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