

**Ecology of Riparian Vegetation
of the Hells Canyon Corridor of
the Snake River: Field Data,
Analysis and Modeling of Plant
Responses to Inundation and
Regulated Flows**

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EXECUTIVE SUMMARY

A study of the ecology of riparian vegetation of the Hells Canyon Corridor of the Snake River was conducted to evaluate current conditions and potential patterns of plant distribution in relation to the different operational flows for the Hells Canyon Complex of dams and reservoirs. The report provides a broad range of analysis of the environmental conditions and riparian vegetation found within the study corridor.

Current vegetation patterns along the corridor are analyzed in Chapter 2. In this analysis, the elevational distributions of 196 riparian plant species were determined along 185 cross-sectional belt transects through the corridor (overall 1.15 transects per mile) and their distribution specifically related to historical water surface patterns of the adjacent river or reservoir, and substrate. For this and subsequent chapters, eight study reaches were investigated: the Weiser reach of the Snake River above Brownlee Reservoir, Brownlee Headwater reach, main Brownlee Reservoir, Powder River Arm of Brownlee Reservoir, Oxbow Reservoir, Oxbow Bypass, Hells Canyon Reservoir and the Snake River downstream from Hells Canyon Dam to the Salmon River confluence.

Along the study corridor, riparian plant species were commonly situated at consistent elevations above the reservoir or river, which this reveals their ecophysiological dependence upon the adjacent water feature. Along the lower reservoirs (Oxbow and Hells Canyon), riparian vegetation occurred in dense bands that extended from the full pool elevation upwards for about 2 m and then upwards for 2 more meters through a transitional zone that contained facultative riparian plants and upland plants. Along the Brownlee Reservoir, riparian vegetation was relatively sparse with ruderal annual plants extending downwards about 5 m below full-pool in relation the draw-down zone of this storage reservoir. More extensive and diverse bands of perennial riparian vegetation occurred along the Snake River downstream of Hells Canyon Reservoir. Along this reach the riparian vegetation was generally fairly dense from the mean annual water level up to about 6 m, with riparian plants tapering off at higher upland elevations (4m +).

Riparian vegetation along all reaches was composed of a combination of native and exotic (introduced) species, with the highest proportion of native plants found along the Snake River below Hells Canyon. Annual and perennial grasses and forbs and woody plants were common along all reaches but varied in terms of their proportion, species occurrence and resultant community types. Woody riparian plants were particularly important for wildlife habitat and the exotic *Amorpha fruticosa* (false indigo) and *Tamarix ramosissima*/*T. parviflora* (tamarisk or salt cedar) were the most abundant and extensive trees along artificial riparian zones of the upper reservoir reaches. In contrast, the native tree/shrub *Celtis reticulata* (hackberry) was dominant along the Snake River below Hells Canyon. Herbaceous plants along the reservoir reaches included a broad range of exotic species such as *Portulca oleraceae* (portulaca) and *Amaranthus albus* and *A. retroflexus* (tumble and redroot pigweeds). The Snake River below Hells Canyon Dam supported more abundant native herbaceous plants such as *Glycyrriza lepidota* (American licorice) along with a few exotic species such as *Physalis longifolia* (long-leaved ground cherry).

Based on their distributions along these reaches and published information about their life-histories and ecophysiology, riparian plants were clustered into six vegetation groups: facultative riparian annuals (FRA), facultative riparian perennials (FRP), hydrophytes (HYD), obligate riparian annuals (ORA), obligate riparian perennials (ORP), or ruderal annuals (RA). The hydrogeomorphic requirements of the six riparian vegetation groups were thus determined and provided the basis for a predictive model that projected establishment, growth and mortality of the plant groups as a function of patterns of water stage (elevation) and velocity.

The model and its predictions are described in Chapter 3. The ‘Hells Canyon_River Environment Model’ (HC_REM) contained specific vegetation modules to assess germination, growth, and inundation-, desiccation- and scour-induced mortalities, and was developed with subsets of the field data and verified by comparison with other field data. Model development and verification included considerations of specific study reaches in relation to their geomorphic context and substrate texture. With a weekly time-step (that was subdivided to account for peak, mean, and end-of-week values), the model predicted water surface elevations and velocities based on a hydraulic model of the river corridor using a multi-decadal dataset that included a wide range of flow conditions.

The HC_REM was applied to model the vegetation responses over a hypothetical time series consisting of three decades of historic data (to develop a modeled representation of current vegetation patterns) combined with 72 years of synthetic data based on the period from 1928 to 1999. Modeled hydrologic conditions were adjusted to account for current water resources development in the basin and current upstream project operations. In the end, the model was run for about a century. In addition to evaluations of output at the end of the modeled run, outputs at decade intervals were assessed to consider possible patterns across specific years that could influence vegetation patterns, particularly among annual plants. The century-long period was considered appropriate to accommodate trees and other long-lived plant species.

Two water management scenarios were compared. A run-of-river (ROR) scenario with no reservoir-regulation simulated water patterns with the reservoirs maintained at (about) full pool. This was contrasted with a scenario proposed by Idaho Power Company (proposed) that involved some regulation of water storage in Brownlee Reservoir and subsequent changes in downstream flows. Each of the two scenarios was input into HC_REM and outputs included projections of elevational distributions and proportions of each of the six vegetation groups for each of seven study reaches (with the exception of the Weiser reach that is upstream of the Hells Canyon Complex and largely unaffected by project operations).

The model subsequently predicted that there would be minimal to moderate differences among vegetation groups for study reaches under the proposed scenario versus the run-of-river scenario. The greatest predicted differences involved the downward expansion of some low-elevational vegetation groups with the proposed scenario that would contrast with a slight reduction in the perennials at the upper end of the riparian zone under that scenario.

The greatest differences would occur along the Brownlee Reservoir reaches with substantial downward extensions of ruderal annuals accompanying periodic draw-downs with the proposed scenario. This was predicted to produce 2- to 5-fold increases in this vegetation group along this reach. Conversely, the reservoir draw-down for the proposed scenario was predicted to disfavor

the facultative riparian perennials that might be reduced by about 10 to 25% along the Brownlee Reservoir reaches.

Minimal differences across the two scenarios were predicted for the study reaches along Oxbow and Hells Canyon reservoirs since the operation and water stage of these reservoirs would not differ significantly between the two scenarios. The model predicted a decrease in ruderal annuals with the proposed scenario; but this prediction was for elevation zones just above full pool. That zone is densely vegetated and since competition was not incorporated into the model this effect is considered unlikely.

The model predicts slight differences in vegetation groups along the Snake River reach below Hells Canyon Dam. Overall, vegetation groups were predicted to differ by less than 10%, a probable limit in the sensitivity of the model.

The plants analyzed included about equal numbers of native (99) and exotic (97) species, including 16 noxious weeds and 4 highly invasive riparian plants. Chapter 4 describes the probable impacts of the different scenarios on these noxious and invasive plants with analyses through HC_REM modeling and consideration of their specific life-history traits. It is predicted that the proposed scenario would favor one or two ruderal annuals weeds along Brownlee Reservoir. Conversely and more substantially, the proposed scenario could limit downstream dispersal and proliferation of some noxious perennials and invasive tree species. This limitation is related to the annual draw-down of Brownlee Reservoir since plants established in the draw-down zone would suffer from drought-stress during extended draw-downs and/or be killed by subsequent inundation. Thus, invasive, exotic perennials would largely be impeded by this water regime. This would probably continue to restrict the downstream expansion of tamarisk along with some other problem plants in the Brownlee Headwater reach.

In Chapter 5, the study addresses the elevational occurrence and possible consequences of the two scenarios on rare plants, with specific detail given to *Cyperus schweintzii*, that occurs along the Snake River below Hells Canyon Dam. This was the only rare plant encountered during our study. Although limited information exists for this species, it occurs primarily on transitional terraces well above the dynamic riparian zone and would thus be minimally affected by reservoir operations and downstream flow management.

Following from these analyses a number of conclusions were reached.

1. The different riparian plant species were commonly situated at consistent elevations relative to the adjacent water features supporting the development and application of a deterministic predictive model.
2. Based on favorable calibration and verification, the HC_REM model appeared to provide a feasible approach to river and reservoir management scenario evaluation. This current application advanced prior hydrogeomorphic approaches to vegetation modeling by adding a cluster of autecological, ecophysiological and life history modules; specifically parameterized for each of six life-forms to allow prediction for different plant life forms for each reach of the study corridor.

3. The application of HC_REM predicted only slight differences between the proposed versus ROR scenarios relative to most of the six vegetation groups across the seven, modeled study reaches. This indicates that with respect to riparian vegetation neither scenario provides a marked benefit or disadvantage relative to the other. Thus, except for Brownlee Reservoir, the lack of major differences in water stage and flow patterns across the scenarios would result in only slight differences in vegetation patterns.
4. Based on the HC_REM assessment and other considerations, it is predicted that the proposed scenario would discourage the downstream expansion of some noxious perennials and invasive woody plants, particularly tamarisk. This restriction in dispersal would result from continuing the periodic draw-down of Brownlee Reservoir Pool, thus inducing mortality due to desiccation during draw-down periods and subsequent inundation with re-filling of the reservoir.

CHAPTER 1: INTRODUCTION AND OBJECTIVES

1.1. Introduction and Objectives

This report provides information regarding the ecology of riparian vegetation along the Hells Canyon corridor of the Snake River and the relationships between riparian plants and water patterns of the adjacent river or reservoir. The work includes field data documenting the current status of vegetation based on cross-sectional transects along the Snake River and reservoirs of the Hells Canyon Complex; Brownlee, Oxbow, and Hells Canyon reservoirs. Statistical and graphical analyses of the data investigate relationships between the current range of plant species, life forms and water level. To predict the responses of riparian vegetation to inundation and regulated flows associated with future operation scenarios, modeling of these responses was conducted utilizing a hydrogeomorphic computer modeling approach that incorporated physical conditions and biological characteristics. Two operating scenarios are modeled that represent operations patterns to be considered as part of the Federal Regulatory Energy Commissions (FERC) relicensing process. A third scenario is also modeled and this represents historic operations, the past pattern that was implemented.

The objectives of the study were to:

1. Collect vegetation transect data to document elevational and longitudinal occurrences of plants to provide a database for statistical and modeling analysis.
2. Conduct statistical and graphical analyses of relationships between vegetation and water surface elevation patterns.
3. Model the response of vegetation to inundation and regulated flows for alternative reservoir operation scenarios.
4. Interpret model outcomes and thus evaluate the probable responses of vegetation to proposed scenarios.

Introductory material, including information regarding the alternative reservoir operation scenarios is presented in Chapter 1. Chapter 2 presents the field data collected at about 200 vegetation transects along the three reservoirs of the Hells Canyon Complex and along the Snake River upstream of the reservoirs and downstream of the Hells Canyon Dam. In Chapter 2, multivariate statistical analyses of these data reveal the relationships of riparian vegetation to long-term water levels in different riparian and fluvial conditions, reservoirs with substantial seasonal draw-down, reservoirs with limited diurnal draw-down, and river reaches upstream and downstream of these reservoirs. Thus, Chapter 2 describes the current occurrence of vegetation and particularly the elevational patterns that reflect the historic water patterns.

In Chapter 3, a predictive model was refined, validated and utilized to project the responses of riparian vegetation to alternative operation scenarios. Chapter 3 explains the various algorithms in the computer model that simulate the interactive processes between variations in flow and

water level and riparian vegetation. Modeled ecophysiological processes include germination and mortality or removal through desiccation, inundation and scour. The model was calibrated and verified by starting the model with barren (unvegetated) substrate and running several decades of historic flow/water level fluctuations to produce a pattern of vegetation for six major life forms or types of vegetation. Predictions of future patterns of vegetation were then made through the HC_REM (Hells Canyon_River Environment Model) model for two scenarios: the proposed operation and a run-of-river (ROR) scenario. Results of the predictions for the two scenarios and a comparison with the historic operations pattern are thus evaluated in Chapter 3. Thus, Chapter 3 projects the future situation under the different operational scenarios.

Chapter 4 analyzes probable impacts of the two operational scenarios on a subset of plants, those that are noxious and invasive weeds. These exotic plants have the capacity to proliferate under various disturbance regimes and can compete with native plants and thus degrade native ecosystems. The two operational scenarios are compared with application of the HC_REM analysis, combined with considerations of the life history traits of particular problem plant species. Hydrochory, water-based dispersal of propagules, seeds or clonal vegetative fragments, is discussed as this relates to the downstream invasion by the noxious and invasive weeds. Thus, Chapter 4 compares the two operational scenarios with respect to future invasion by noxious weeds.

Chapter 5 discusses the issues and findings regarding the effects of the two operations scenarios on rare plant species along the study corridor, with a focus on *Cyperus schweinitzii*, the only rare plant species encountered in the present study. The analysis again applies consideration of the plant's current elevational distribution relative to historic water patterns and subsequently provides interpretive prediction about the impacts of the two operational scenarios on its future condition.

The closing chapter, Chapter 6 integrates the findings and predictions of the prior chapters. It provides an overall discussion and evaluation of the study results with an emphasis on the comparison of predicted responses under the two different operational scenarios. Chapter 6 thus integrates the results from the prior chapters and applies some professional judgement relative to the interpretation of the model outputs. It thus compares the probable consequences of the two operational scenarios, the IPC proposed operating (proposed) scenario and the ROR scenario, on riparian vegetation along the reservoir and river reaches. Following Chapter 6 a sequence of appendices provide supplemental information that was considered in the analyses.

1.2. Study Area

1.2.1. Location

The Hells Canyon Reach of the Snake River is situated between west-central Idaho and northwestern Oregon (Figure 1.1.). The Hells Canyon Complex (HCC) generation facilities are located along the Snake River valley in the southern portion of Hells Canyon and are comprised of three sequential reservoirs, Brownlee, Oxbow, and Hells Canyon. The Snake River reach below Hells Canyon Dam is unimpounded, although the three-dam complex seasonally

influences river flows. The Hells Canyon Relicensing Study Area for evaluating terrestrial resources (Idaho Power Company 1997) is located between the town of Weiser and the confluence of the Salmon and Snake Rivers, from approximately river mile (RM) 351 to RM 188.

The Snake River, a major tributary to the Columbia River, is the focal point of Hells Canyon. In this location the river flows northward and forms part of the boundary between Idaho and Oregon and subsequently between Idaho and southeastern Washington. Federal agencies, including the Bureau of Land Management (BLM) and U.S. Forest Service, are responsible for managing the majority of public land in Hells Canyon. These areas fall within the jurisdictional boundaries of the Wallowa–Whitman National Forest, Oregon; Payette National Forest, Idaho; Nez Perce National Forest, Idaho; Four Rivers Field Office (FO) of the Lower Snake River District, BLM–Idaho; Cottonwood FO of the Upper Columbia-Salmon Clearwater District, BLM–Idaho; and Baker FO and Malheur FO of the Vale District, BLM–Oregon. Other agencies with natural resource jurisdiction in the greater project area include the U.S. Department of the Interior (USDI), National Marine Fisheries Service, USDI Bureau of Indian Affairs, USDI Fish and Wildlife Service, and state agencies from Idaho and Oregon.

1.2.2. Study Reaches

Our study area included the Snake River reach of Hells Canyon from the bridge (RM 351.2) at Weiser, Idaho, downstream to the confluence of the Snake and Salmon Rivers (RM 188.2) (Figure 1.1.). The study area was divided into eight reaches.

1. Weiser Reach—Weiser Bridge in Weiser, Idaho, to the headwaters of Brownlee Reservoir, at Farewell Bend, Oregon (River mile 351.2 to 342.9).
2. Brownlee Headwaters Reach—The upstream portion of Brownlee Reservoir with the inflowing zone of the Snake River that provides the transition from riverine to reservoir condition depending on reservoir level (River mile 342.9 to 326.0).
3. Powder River Arm—The Powder River arm of Brownlee Reservoir (River mile 295.7).
4. Main Brownlee—The main body of Brownlee Reservoir excluding the Headwaters Reach and the Powder River Arm Reach (River mile 326.0 to 284.5).
5. Oxbow Reservoir Reach—The main body of Oxbow Reservoir (River mile 284.5 to 272.8).
6. Oxbow Bypass Reach—The reach of river downstream of Oxbow Dam to the turbine release from Oxbow Dam (River mile 272.7 to 270.1).
7. Hells Canyon Reservoir Reach—The main body of Hells Canyon Reservoir (River mile 270.1 to 241.1).
8. Snake River Reach—The Snake River downstream of Hells Canyon Dam to the confluence with the Salmon River (River mile 247.7 to 188.2).

1.2.3. Physiography

Hells Canyon is one of the deepest and most rugged river gorges in the continental United States. It ranges between 2,000 and 3,000 ft deep from Weiser to Oxbow Dam. Below Oxbow Dam, the river enters a narrow, steep-sided chasm measuring up to 5,500 ft deep. From the confluence with the Grande Ronde River, the Snake River then flows into a lava-filled basin and through a much shallower canyon to Lewiston, Idaho (DOE 1985). The elevation of the Snake River near Weiser, Idaho, is about 2,090 ft above mean sea level (msl), descending to about 910 ft msl at the confluence of the Salmon River, about 59 mi below Hells Canyon Dam.

Throughout Hells Canyon, topography is generally steep and broken, with slopes often dominated by rock outcrops and talus slopes. At the deepest points, canyon walls rise almost vertically. Canyon walls are also deeply dissected by numerous side canyons with tributaries to the Snake River. The Seven Devils Mountains to the east and the Wallowa Mountains to the west form the upper reaches of the canyon walls. These mountains form a series of jagged peaks reaching almost 10,000 ft, with subalpine and alpine conditions (USDA 1990).

1.2.4. Land Features and Geology

Hells Canyon consists of a series of folded and faulted metamorphosed sediments and volcanics overlain unconformably by nearly horizontal flows of Columbia River basalt. This basalt group covered much of eastern Washington, northern Oregon, and adjacent parts of Idaho (Bush and Seward 1992). The older rocks in the series are Permian to Jurassic in age and represent at least two episodes of island arc volcanism and adjacent marine sedimentation similar to those found today in the Aleutian Islands west of Alaska. These rock units represent old island arc chains that were sequentially “welded” to the west coast of North America during the late Paleozoic and early to mid-Mesozoic eras by subduction of a tectonic plate beneath the North American continental tectonic plate (Asherin and Claar 1976, USDA 1994b).

In more recent geologic time, the Snake River formed Hells Canyon through erosion of the Blue Mountains in Oregon and Seven Devils Mountains in Idaho (DOE 1985). The Snake River has existed since the Pliocene and probably cut to its present level in Hells Canyon during the Pleistocene. During the Pleistocene, glacial meltwater provided abundant runoff for down-cutting, while regional uplifting created weak points in the 2,000- to 3,000-foot-thick basalt plateau that overlaid the Blue and Seven Devils mountains. Resulting erosion formed the currently observed drainage pattern that established the Snake River (DOE 1985). Northeast-trending, high-angle fault patterns characterize the extensive Snake River fault system running throughout the study area (Fitzgerald 1982).

Besides basalt, other rock types are also present within the study area. Extensive limestone outcrops are found in some tributary drainage areas, along with local granitic outcrops.

1.2.5. Soils

The soils throughout Hells Canyon are derived primarily from Columbia River basalt, covered in most areas with a thin mantle of residual soils from weathered native rock. Isolated areas contain

deposits of windblown silt. Unconsolidated materials include ash-loess from the Mount Mazama eruption 6,900 years ago, river sands and gravel deposited during the Bonneville floods 15,000 years ago, and colluvium and talus deposited more recently. The amount of soil cover declines northward through Hells Canyon. Near Hells Canyon Dam (RM 247), most rock faces are nearly vertical with little soil cover (USDA 1994b).

Most soil complexes are well drained and vary from very shallow to moderately deep. Loams are the dominant textural class and vary from very stony to silty, often with a clay subsoil component (NRCS 1995).

1.2.6. Fluvial Processes

In the upstream reach, the Snake River is characterized as a low-gradient (0.2 to 0.4 m/km) river, with several island complexes. Agriculture and rural development on flat to gentle topography surround this reach. Large amounts of irrigation returns cause high turbidities and increased nutrient loading. Brownlee Reservoir is a steep-sided reservoir with a maximum depth approaching 300 ft near the dam. Large rock outcrops occur throughout its entire length. Oxbow Reservoir is a relatively small and shallow re-regulating reservoir surrounded by moderate to steep topography (20% to 75% slopes). Shorelines are primarily basalt outcrops and talus, except for alluvial fans associated with small tributaries. Hells Canyon Reservoir is a re-regulating reservoir with maximum depths approaching 200 ft. Reservoir shorelines are very steep, and substrates are primarily composed of basalt outcrops and talus slopes. The Snake River downstream of Hells Canyon Dam is a high-gradient river (1.8 m/km) bounded by nearly vertical cliff faces. The Snake River below Hells Canyon Dam supports a diversity of aquatic habitats, including numerous large rapids, shallow riffles, and deep pools. Substrates are also diverse, ranging from large basalt outcrops and boulders to cobble/sand bars.

In the alluvial valley portion of the study area (upstream of Brownlee Reservoir), the river, its bed and banks, and associated riparian habitat can interact dynamically since bed and bank material are small enough to be mobilized periodically. In the canyon portion, interaction between the river and its bed and banks is limited to areas that can potentially be mobilized by the flow, such as some bars, islands, terraces, and fans. Some of these areas consist of finer sediment particles such as sand and gravel instead of bedrock or coarse colluvial boulder canyon walls and hillsides that dominate much of Hells Canyon leaving most of the canyon geomorphically very stable and inactive. Geomorphic features, including hill slopes, terraces, bars, and fans, as well as a description of sediment type (rock, boulder, cobble, gravel, and sand) were delineated in a geomorphic classification of the Snake River from Hells Canyon Dam to Asotin, WA (Miller and others 2002). This information is useful in interpreting the effect of flow and different operating regimes on geomorphology and vegetation. The geomorphic classification supports the concept that Hells Canyon is quite stable from a geomorphic perspective. This is supported by Vallier (1998) who conducted extensive geologic studies in Hells Canyon. Vallier (1998) concluded that the canyon has not significantly changed for quite some time: "If one were to step back 50,000 years, perhaps even 100,000 years, there would be very little change in Hells Canyon. Vallier (1998) stated that although the canyon is probably a little deeper today, the same tributary streams and even some of the same gravel bars would be recognizable. These statements are consistent with Rosgen's general characterization of

F1 streams (the Rosgen classification of Hells Canyon) as being “very stable” and having “not changed or significantly adjusted in modern times.”

While such stability is the general case, certain geomorphic features and material types, particularly those that consist of finer sized sediment or those that are most strongly affected by the current, may be subject to change and influence by modified flow regimes. Even if the canyon has not changed from a general geomorphic perspective, it could be changed on a localized perspective depending on certain aspects of key geomorphic features, which, in turn may affect hydraulics, vegetation, habitat, or wildlife. Knowing the distribution of geomorphic features, along with other site-specific data, and their sensitivities to water flow can be useful for flow regime planning, as well as stabilization or protection measure planning.

Sediment trapping by upstream reservoirs, as well as by the Hells Canyon Complex, has reduced the sediment supplied to and transported through the study reach. In Hells Canyon, the gradient of the river steepens, and the flow becomes more swift and turbulent. The steeper, faster flow increases sediment transport capacity and only allows limited deposition of fine sediment. Fine sediment supplies have been reduced in recent decades due to significant upstream water resources development throughout the Snake River basin and associated tributaries and increased regulatory control of land-use disturbances. Discussion of this issue is presented in later chapters of the report regarding their potential effects on riparian vegetation.

1.2.7. Climate

Located in the High Desert region, climate in Hells Canyon is significantly influenced by the rain shadow of the Cascade Mountains to the west. From late fall to early spring, the climate of west-central Idaho and eastern Oregon is typically influenced by cool and moist Pacific maritime air. Periodically this westerly flow is interrupted by outbreaks of cold, dry continental air from the north, which is normally blocked by mountain ranges to the east. During the summer, a Pacific high-pressure system dominates weather patterns, resulting in minimal precipitation and more continental climatic conditions overall (Ross and Savage 1967).

Climatological information is summarized for Weiser, Richland, Brownlee Dam, and Lewiston (Figure 1.2.). Average annual precipitation is lowest at the southern end of the study area (Weiser, 286 mm), increases northward (Richland, 298 mm), peaks around Brownlee Dam (445 mm), and declines towards Lewiston (326 mm). The average annual precipitation ranges from about 380 to 500 mm (15 to 20 inches), depending on elevation. Nearly 45% of the average annual precipitation at Brownlee Dam (445 mm [17.8 inches]) falls from November through January, which strongly contrasts with the 9% average recorded for July through September. Thus, most precipitation occurs in spring and winter, (Tisdale et al. 1969, Tisdale 1986, Johnson and Simon 1987), and little or no precipitation falls during the hottest months of summer. Average annual evapotranspiration is estimated to be about 1,300 mm (52 inches).

Mean annual temperatures are similar among the four weather stations. Generally, the climate tends to become drier and warmer downstream of Brownlee Dam. Climatological information from Brownlee Dam (RM 284.6) is probably characteristic of the central section of the study area. The canyon bottom area is dry with seasonal temperatures ranging from lows of about -5°C in January to highs of about 35°C in July. Temperatures below freezing are

normally experienced from mid-November through mid-April. As a rule, winters in the canyons are mild, while summers on the canyon floor can be hot. Mean temperatures above 2,000 m (6,562 ft msl) range from -9°C in January to 13°C in July. By contrast, mean temperatures below 1,000 m (3281 ft msl) elevation range from 0°C in January to between 28°C and 33°C in July (Johnson and Simon 1987).

1.2.8. Vegetation

The types of vegetation growing along the canyon slopes of the Snake River are the result of three primary ecological factors: topography, soils, and climate. Climate exerts the strongest influence on the development of plant life. The relatively mild winters below the canyon rim have allowed the development of disjunct species such as hackberry (*Celtis reticulata*), which is most often found in the southwestern states, though it commonly occurs in the middle and lower Snake River area (Tisdale 1979, DeBolt 1992).

Within the context of regional climate, topography is a major influence on the development and distribution of vegetation (Tisdale et al. 1969, Tisdale 1979, Tisdale 1986). The topographical complexity of Hells Canyon has produced a mosaic of vegetation types (Tisdale 1979, BPA 1984, USDI 1987). Grassland, shrubland, riparian, and coniferous forest communities exist in close proximity. Interfingering of grassland and forest, for example, occurs at a number of sites throughout the canyon due to variations in aspect (Tisdale 1979).

Twenty-six cover types were identified along the Snake River in the Hells Canyon Study Area (Holmstead 2001). The area classified by Holmstead (2001) covered up to approximately one half mile on both sides of the Snake River or associated reservoirs and from above Brownlee Reservoir at the town of Weiser, Idaho (RM 351.2), downstream to the confluence of the Salmon River (RM 188.2). The dominant cover types were *Grassland* (35.5%), *Shrub Savanna* (21.0%), *Lotic* (16.1%), *Shrubland* (6.6%), and *Cliff/Talus* (5.6%) All remaining cover types covered less than 5% of the area classified.

Wetland and Riparian-Dominated Vegetation Types

A narrow band of diverse riparian communities intermittently follows the course of the Snake River and its many tributaries. Although limited in geographic area, this riparian zone is vital because of its biological diversity. Emergent wetland communities are composed mostly of broad-leaved pepperweed (*Lepidium latifolium*), marsh grass (*Heleochoa alopecuroides*), purple loosestrife (*Lythrum salicaria*), common cocklebur (*Xanthium strumarium*), hemp dogbane (*Apocynum cannabinum*), alkali saltgrass (*Distichlis stricta*), and purslane (*Portulaca oleracea*). Predominant shrub species in riparian areas include netleaf hackberry (*Celtis reticulata*), false indigo (*Amorpha fruticosa*), coyote willow (*Salix exigua*), common chokecherry (*Prunus virginiana*), poison ivy (*Toxicodendron radicans*), syringa (or mock orange, *Philadelphus lewisii*), Himalayan blackberry (*Rubus discolor*), and tamarisk (*Tamarix parviflora*).

Predominant tree species include water birch (*Betula occidentalis*), white alder (*Alnus rhombifolia*), black cottonwood (*Populus trichocarpa*), silver maple (*Acer saccharinum*), and

peachleaf willow (*Salix amygdaloides*). Most weedy exotic species occur at and above the headwaters of Brownlee Reservoir (Holmstead 2001).

Many shoreline sections have no riparian vegetation. Rather, upland vegetation on steep canyon slopes simply meets the rocky shoreline. Grassland and shrubland communities are common along much of the Snake River and its tributaries.

Herbaceous-Dominated Vegetation Types

The dry climate and typically stony, shallow soils of the canyon have favored the development of grassland steppe communities at the lower and middle elevations (Tisdale 1979, Tisdale 1986). Commonly occurring grass species in the study area include bunchgrasses such as bluebunch wheatgrass (*Agropyron spicatum*) and Idaho fescue (*Festuca idahoensis*), and annual grasses such as cheatgrass (*Bromus tectorum*) and medusahead wildrye (*Taeniatherum caput-medusae*) (Holmstead 2001). Other grasses such as sand dropseed (*Sporobolus cryptandrus*) and red threeawn (*Aristida longiseta*) are locally common (BPA 1984, Tisdale 1986).

Shrub-Dominated Vegetation Types

Shrub species comprise a large segment of the canyon's overall vegetation composition. Shrub-steppe vegetation types occur at mid-elevations in the Hells Canyon Study Area, especially in its southern region (Bonneville Power Administration 1984). Commonly occurring shrubs include big sagebrush (*Artemisia tridentata*), bitterbrush (*Purshia tridentata*), gray rabbitbrush (*Chrysothamnus nauseosus*), hackberry, serviceberry (*Amelanchier alnifolia*), and bitter cherry (*Prunus emarginata*) (Bonneville Power Administration 1984, Tisdale 1986, Holmstead 2001). For the most part, sagebrush stands are limited to the area around Brownlee Reservoir. In these stands, the herbaceous layer is dominated by cheatgrass, with a variety of forbs.

Stands of hackberry can be found throughout the study area, either on lower slopes with rocky residual/colluvial soil or on alluvial terraces with sandy soil (Tisdale 1986). In these stands, hackberry is often mixed with a number of other shrub and tree species, including antelope bitterbrush, blue elderberry (*Sambucus cerulea*), and ponderosa pine (BPA 1984). Poison ivy is also abundant. The herbaceous layer is most often dominated by bluebunch wheatgrass, with cheatgrass dominant in those areas moderately to heavily disturbed by past livestock use.

Tree-Dominated Vegetation Types

Although coniferous forest communities are generally restricted to the higher elevations of steep canyon slopes, they do reach down as far as the river at certain locations. For example, stands of ponderosa pine (*Pinus ponderosa*) or Douglas fir (*Psuedotsuga menziesii*), typically with a common snowberry (*Symphoricarpos albus*) understory, extend to the river on north-facing slopes at sites around the main bodies of Oxbow and Hells Canyon reservoirs, and downstream of Hells Canyon Dam (Holmstead 2001).

1.2.9. Land Use

Although the Hells Canyon area has been used by humans from about 10,000 years ago, it has generally remained a sparsely settled and relatively inhospitable landscape (Blair et al. 2001). Human impacts dramatically increased with European settlement that commenced in about the mid-19th century. Mining became prominent by the late 1800s with strikes of gold, copper and silver. Farming followed and was modest, including fruit orchards and grain farms. Ranching was more substantial with sequential changes of the dominant livestock from cattle to sheep, then back to cattle. Both the mining and agricultural activities had substantial impacts on the vegetation and wildlife resources along the Snake River through Hells Canyon (Blair et al. 2001). These human activities disturbed and degraded vegetation communities in many riparian areas and introduced exotic weeds. The impacts from livestock grazing would have been particularly extensive and severe and due to the semi-arid climate; even after release from grazing pressure, vegetation recovery would be very slow.

Due to inaccessibility and limited woodland resources, timber harvesting was minimal along Hells Canyon (Blair et al. 2001). Exceptions would have involved riparian woodlands along side-tributaries near local settlements and mines where trees would have been harvested to provide materials for shelter construction and mine timbers or harvested for fuel wood. These impacts would have been substantial but localized. While localized development caused intense impacts, the various development activities throughout the history of Hells Canyon remained quite limited in aerial extent due primarily to the dominance of steep, rocky slopes that were not amenable to significant development.

1.3. Project Operations

1.3.1. Current Operations

Hells Canyon contains IPC's largest hydroelectric generating complex, the Hells Canyon Complex (HCC). The HCC includes the Brownlee, Oxbow, and Hells Canyon dams, reservoirs, and power plants. Operations of the three projects of the complex are closely coordinated to generate electricity and to serve other public purposes.

IPC operates the complex to comply with the FERC license, as well as to accommodate other concerns, such as recreational use, environmental conditions and voluntary arrangements. Among these arrangements are the 1980 *Hells Canyon Settlement Agreement*, the *Idaho Power Fall Chinook Interim Recovery Plan and Study* adopted in 1991, and between 1995 and 2001, the cooperative arrangement that IPC had with federal interests in implementing portions of the Federal Columbia River Power System (FCRPS) biological opinion flow augmentation, which is intended to avoid jeopardy of the FCRPS operations below the HCC.

Brownlee Reservoir is the only one of the three HCC facilities - and IPC's only project - with significant storage. It has 101 vertical feet of active storage capacity, which equals approximately 1 million acre-feet of water. On the other hand, Oxbow and Hells Canyon

reservoirs have significantly smaller active storage capacities, about 0.5 and 1.0% of Brownlee Reservoir's volume, respectively.

Brownlee Dam's hydraulic capacity is also the largest of the three projects. Its powerhouse capacity is approximately 35,000 cubic feet per second (cfs), while the Oxbow and Hells Canyon powerhouses have hydraulic capacities of 28,000 and 30,500 cfs, respectively.

Target elevations for Brownlee Reservoir define the flow through the HCC. However, when flows exceed powerhouse capacity for any of the projects, water is released over the spillways at those projects. When flows through the HCC are below hydraulic capacity, all three projects operate closely together to re-regulate flows through the Oxbow and Hells Canyon projects so that they remain within the 1-foot per hour ramp rate requirement (measured at Johnson Bar below Hells Canyon Dam) and meet daily peak load demands.

In addition to maintaining the ramp rate, IPC maintains minimum flow rates in the Snake River downstream of Hells Canyon Dam. These minimum flow rates are for navigation purposes and IPC's compliance with article 43 of the existing license. Neither the Brownlee Project nor the Oxbow Project has a minimum flow requirement below its powerhouse. However, because of the Oxbow Project's unique configuration, a flow of 100 cfs is maintained through the bypassed reach of the Snake River below the dam (a segment called the Oxbow Bypass).

1.3.2. Alternative Operation Scenarios for Analysis in the Relicensing Process

Two operation scenarios have been prepared for analysis and evaluation of the various issues included in the relicensing studies. These are:

1. Proposed operations (proposed)
2. Run-of-river operations (ROR)

Operational analyses use the proposed operation of the HCC as the base case scenario, which defines the operational parameters under which the complex would typically operate. Proposed operations for the HCC provide for flood control in the spring, water releases for fall chinook, and other constraints to operations, such as reservoir fluctuation limits (Parkinson 2002).

Varying hydrologic conditions and numerous other factors influence the way hydropower projects operate. Daily operations are influenced by many factors, which may include project inflow, energy demand, market conditions, or emergency situations and are difficult to predict on a long-term basis with any certainty. Therefore, for the purposes of the relicensing studies, the term "operations" is defined generally. In addition, IPC's definition of proposed project operations looks forward into the new license term and provides a general point of comparison for other potential operating scenarios. It is important to note that, if the output of IPC's operations model were compared with historical conditions, differences would be apparent. Therefore, the comparison between proposed scenarios and past conditions should be cautiously undertaken.

Parameters of the proposed operations scenario for the HCC differ considerably from the operating parameters of the original license. Over time, energy and environmental conditions

have altered operational considerations. For example, when fall chinook salmon were designated as threatened under the Endangered Species Act, IPC modified its operations. In the fall of 1991, IPC started a program to protect spawning adults and emerging fry. IPC's proposed operations continue this special program.

The ROR is the operational scenario that IPC will compare with the base case scenario (proposed operations) to determine project impacts. ROR establishes a scenario where inflows to the HCC from the Snake River and its tributaries will equal outflows from the HCC. This scenario does not necessarily reflect conditions that would be most beneficial to environmental resources. Rather, it reflects a condition in which IPC could analyze potential impacts with the project in place but without project operations influencing the outflow hydrograph. A complete description of input parameters for each scenario of the operations model is presented in Parkinson (2001).

Additional details of the alternative scenarios are provided below to more fully understand specific conditions used in evaluating their impacts with regard to terrestrial resources.

Proposed Operating Scenario (Base Case, IPC Scenario)

The COE's North Pacific Division defines flood-control requirements and coordinates flood-control efforts with IPC. During the spring, IPC complies with article 42 and responds to the COE request to lower the water level in Brownlee Reservoir. The lower water level provides space for excess spring runoff and helps prevent flooding, primarily on the lower Columbia and lower Snake Rivers.

CHEOPS™, a simulation package for hydropower systems designed by Duke Engineering & Services (DE&S), evaluates physical and operational changes at multiple-development hydroelectric projects. The CHEOPS model uses the latest 1998 rule curve formulas to calculate the target elevations for Brownlee Reservoir based on observed flows at Brownlee and The Dalles. The model begins drafting Brownlee Reservoir (lowering its water level) after January 7th for each year. This drafting simulates IPC's flood-control requirements by reaching calculated target elevations for February 28, March 31, April 15, and April 30 again, based on the observed flows. The model begins refilling Brownlee Reservoir after the calculated April 30th target. The refill target is 2,069 ft above sea level or higher by the first week in June and full (2,077 ft) by the latter part of June. Meeting this target ensures that enough water is stored in the reservoir to meet peak summer electricity demands, provide suitable spawning habitat for resident fish, and offer optimal recreational opportunities, particularly through the Fourth of July holiday. After the Fourth of July holiday, the model again drafts the reservoir beginning July 5th each year to simulate IPC customers' power needs during the summer months. The amount of draft varies according to the type of water year and the target elevation specified for August 31 (Table 1.1.).

Historically and in the future, Brownlee Reservoir elevations may be higher or lower than those specified in the model constraints. The elevations used in the model are considered "typical" and actual reservoir elevations by August 31 will be a function of IPC's system or load needs and seasonal hydrologic or climatic conditions.

During the fall, Brownlee Reservoir is operated largely to benefit the fall chinook below the HCC. To maintain stable spawning conditions for fall chinook, water is released from Brownlee

Reservoir before the spawning period to allow the reservoir to capture fall inflows and maintain a constant flow below Hells Canyon Dam.

To calculate the target elevation for Brownlee Reservoir, the model calculates the difference between the total inflow volume during the spawning season and the constant set spawning flow released during the fall chinook program. The model is configured to begin drafting Brownlee Reservoir by September 9th (sometime after Labor Day weekend, to provide access to boat ramps for recreation before the fall chinook program begins) to capture the inflow volume. The type of water year will determine the spawning flow released below the HCC in the model. The spawning season is defined in the model as beginning October 21 through December 11 for each year. After the spawning season is complete, the minimum instantaneous flow volume below Hells Canyon Dam is reduced slightly below the fall spawning flow, assuming that water will be maintained over the shallow-most redd through fry emergence in the spring. After fry emergence, or June 1st in the model, the minimum instantaneous flow below Hells Canyon Dam is reduced to 6,500 cfs, or inflows such that Brownlee Reservoir is not drafted to meet the minimum flow requirement. Table 1.2. summarizes the minimum instantaneous flows below Hells Canyon Dam.

The spawning season and associated minimum flows vary among years. The minimum instantaneous flows listed in Table 1.2. are considered “typical” for modeling purposes. For example, constant spawning flow for fall chinook beginning in October 2001 was 8,000 cfs. In addition, IPC’s license stipulates a minimum flow of 5,000 cfs below Hells Canyon dam. Other minimum flows currently govern project operations as a result of various agreements primarily associated with the protection of salmon.

No license-required minimum flows apply below Brownlee or Oxbow dams. Other operational constraints that apply to the operations model include reservoir-level fluctuation limits and ramp rates (Tables 1.3. and 1.4.). These constraints define the typical operational scheme for HCC model simulations.

Because of its unique configuration, only the Oxbow Project has a minimum bypass-flow requirement of 100 cfs in the existing license. This bypass flow is released from the dam and is discharged into the bypass section where it combines with discharges from the powerhouse. Flows exceeding powerhouse capacity are also discharged into the bypassed reach of the Snake River below the dam (a segment called the Oxbow Bypass).

Only the Hells Canyon Project has a license-restricted ramping rate. Its compliance is measured at Johnson Bar, located approximately 17.6 river miles downstream of the dam (Tables 1.5. and 1.6.).

IPC’s self-imposed daily limit of 10,000 cfs during the recreation months is also utilized in the model simulations. Again, this daily limit is self-imposed and is utilized to represent “typical” operations between June 1 and September 30. Historically, 80 percent of the time daily fluctuations below Hells Canyon were 10,000 cfs or below. Therefore, the remaining 20 percent of the exceedances during this time period were not modeled by CHEOPS.

1.3.2.1. Run-of-river Operations

IPC uses ROR operational scenarios to evaluate HCC project impacts. The ROR operational scenario represents maintaining the HCC in place without the influence of operations. Within the scenario and for all types of water years, Brownlee Reservoir will be maintained at elevation 2,077 ft for the entire year. Similarly, Oxbow and Hells Canyon reservoirs will be held at 1,805 ft and 1,688 ft, respectively (see also Table 1.3.). Spill will occur at any of the projects when the hydraulic capacity is exceeded. Inflow to the projects will be the same as for proposed operations on a daily average basis. Because the projects will be passing a constant daily average inflow, ramp-rate restrictions below Hells Canyon Dam are not applicable. Also, flood control and the fall chinook program will not be simulated in this scenario. Tables 1.7. and 1.8. illustrate the model settings or boundary conditions for this scenario.

In the ROR scenario, each reservoir will be held at maximum pool elevation and will pass daily average inflow. Load following will not occur at any of the projects because that would cause reservoir level and project discharges to fluctuate over the course of the day (Table 1.8.).

Because of its unique configuration, only the Oxbow Project has a minimum bypass flow requirement of 100 cfs in the existing license. This scenario also maintains the bypass flow released from the dam and discharged into the bypass section where it combines with discharges from the powerhouse. Flows exceeding powerhouse capacity are also discharged into the bypassed reach of the Snake River below the dam.

As mentioned previously, the ramp-rate restriction below Hells Canyon Dam is not applicable within the ROR scenario (Table 1.9.). A constant daily average inflow is passed through the project without operations influencing the hydrograph.

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Table 1.1. Modeled operations of the HCC for power needs (base case).

| Type of Water Year | Brownlee Target Elevation for August 31 |
|---------------------------|--|
| Low | 2072 ft |
| Medium | 2069 ft |
| High | 2059 ft |

Table 1.2. Modeled minimum flows below Hells Canyon Dam (proposed operations).

| Time Period | Type of Water Year | Minimum Instantaneous Flow (cfs) |
|------------------------|-------------------------------|---|
| December 12–June 1 | Low | 8,500 |
| | Medium | 10,500 |
| | High | 12,000 |
| June 2–October 20 | Low | 6,500 |
| | Medium | 6,500 |
| | High | 6,500 |
| October 21–December 11 | Low | 9,000 |
| | Medium | 11,500 |
| | High | 13,000 |

Table 1.3. Modeled HCC Reservoir elevation limits under the proposed operations scenario.

| Project | Maximum Elevation | Minimum Elevation |
|------------------------|--------------------------|--------------------------|
| Brownlee Reservoir | 2,077 ft above msl | 1,976 ft above msl |
| Oxbow Reservoir | 1,805 ft above msl | 1,800 ft above msl |
| Hells Canyon Reservoir | 1,688 ft above msl | 1,683 ft above msl |

Table 1.4. Modeled HCC reservoir-level fluctuation limits under the proposed operations scenario.

| Project | Daily Fluctuation Limits |
|-------------------------------|---|
| Brownlee Reservoir | |
| January 1 through May 20 | 3 ft per day |
| May 21 through June 21 | 1 ft per day for resident fish spawning |
| June 21 through December 31 | 3 ft per day |
| Oxbow Reservoir | |
| January 1 through December 31 | 5 ft per day |
| Hells Canyon Reservoir | |
| January 1 through December 31 | 5 ft per day |

Table 1.5. Modeled ramping rate restrictions at Hells Canyon Dam under the proposed operations scenario.

| Hells Canyon Ramping Rate Operations | Ramping Rate Limits |
|--|---|
| Ramp rate restrictions: | |
| Ramping rate up | 1 ft per hour |
| Ramping rate down | 1 ft per hour |
| Daily limit between minimum and maximum flows: | |
| June 1 through September 30 | 10,000 cfs per day |
| October 21 through December 11 | No load following during fall chinook program |

Table 1.6. Modeled minimum flows below Hells Canyon Dam under the ROR scenario, January 1 through December 31.

| Type of Water Year | Minimum Instantaneous Flow |
|---------------------------|-----------------------------------|
| Low | Not Applicable |
| Medium | Not Applicable |
| High | Not Applicable |

Table 1.7. Modeled HCC reservoir elevation limits under the ROR scenario.

| Project | Maximum Elevation | Minimum Elevation |
|------------------------|--------------------------|--------------------------|
| Brownlee Reservoir | 2,077 ft above msl | 2,077 ft above msl |
| Oxbow Reservoir | 1,805 ft above msl | 1,805 ft above msl |
| Hells Canyon Reservoir | 1,688 ft above msl | 1,688 ft above msl |

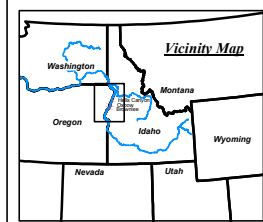
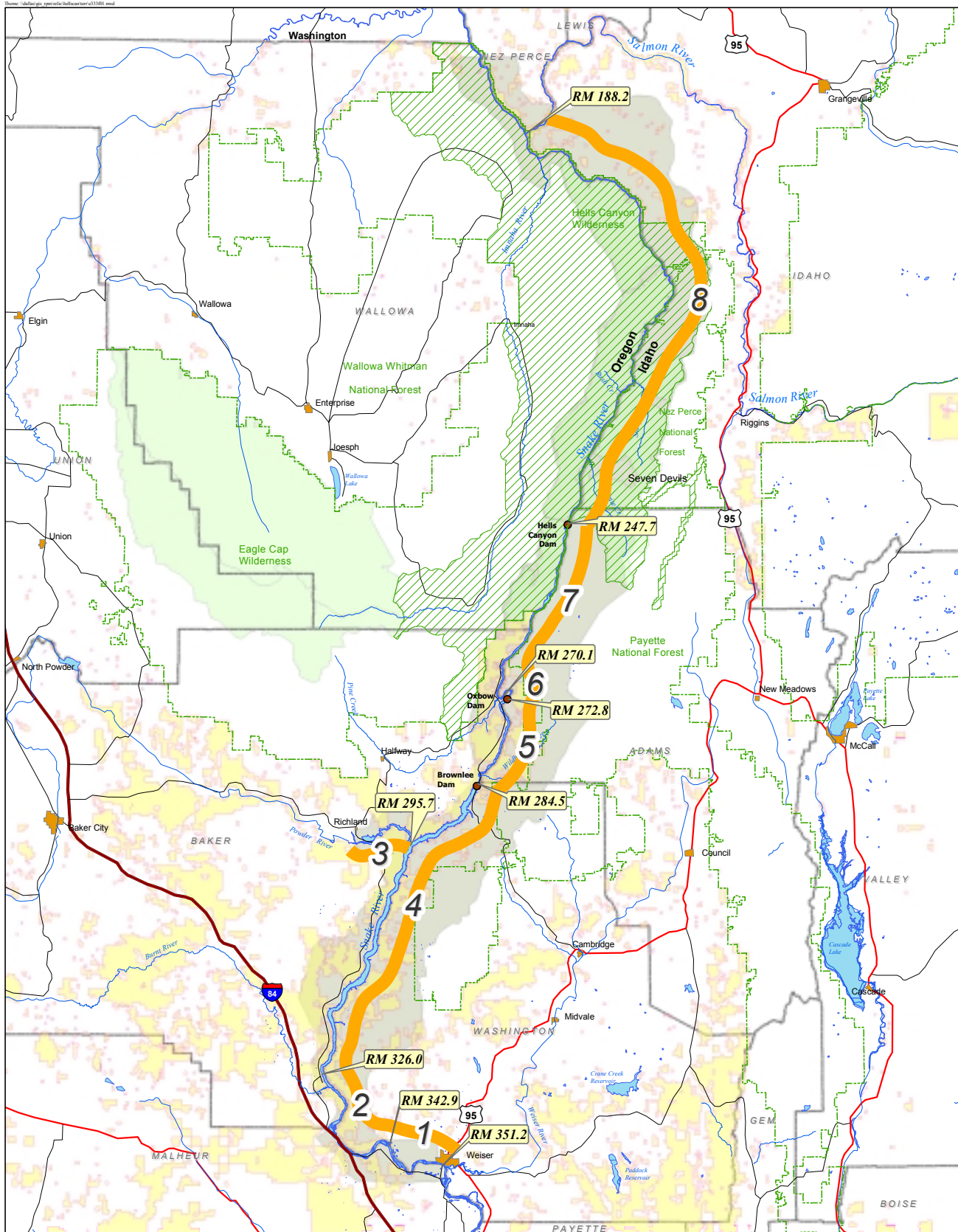
Table 1.8. Modeled HCC reservoir-level fluctuation limits under the ROR scenario.

| Project | Daily Fluctuation Limits |
|-------------------------------|---------------------------------|
| Brownlee Reservoir | |
| January 1 through December 31 | 0 ft per day |
| Oxbow Reservoir | |
| January 1 through December 31 | 0 ft per day |
| Hells Canyon Reservoir | |
| January 1 through December 31 | 0 ft per day |

Table 1.9. Modeled ramping rate restrictions below Hells Canyon Dam under the ROR scenario.

| Hells Canyon | Ramping Rate Limits |
|---|----------------------------|
| Ramp rate restrictions: | |
| Ramping rate up | Not applicable |
| Ramping rate down | Not applicable |
| Daily limit between minimum and maximum flow: | |
| April 1 through September 30 | Not applicable |
| October 21 through December 11 | Not applicable |

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Features Legend

- Forest Service Boundaries
 - River
 - Water Body
 - Hells Canyon N.R.A.
 - Urban Areas
 - BLM
 - County Boundaries
 - Wilderness Area
 - Interstate Highway
 - State Highway
 - Major Road
 - Rim-to-Rim Study Area (Tier 2)
1. Weiser Reach - RM 351.2 to 342.9
 2. Brownlee Headwaters Reach - RM 342.9 to 326.0
 3. Powder River Arm - RM 295.7
 4. Main Brownlee - RM 326.0 to 284.5
 5. Oxbow Reservoir Reach - RM 284.5 to 272.8
 6. Oxbow Bypass Reach - RM 272.7 - 270.1
 7. Hells Canyon Reservoir Reach - RM 270.1 to 247.7
 8. Snake River Reach - RM 247.7 to 188.2

Tech. Report E.3-3-3 Figure 1-1
HELLS CANYON HYDROELECTRIC COMPLEX
Location of the Hells Canyon Complex
Study Area and Sampling Reaches



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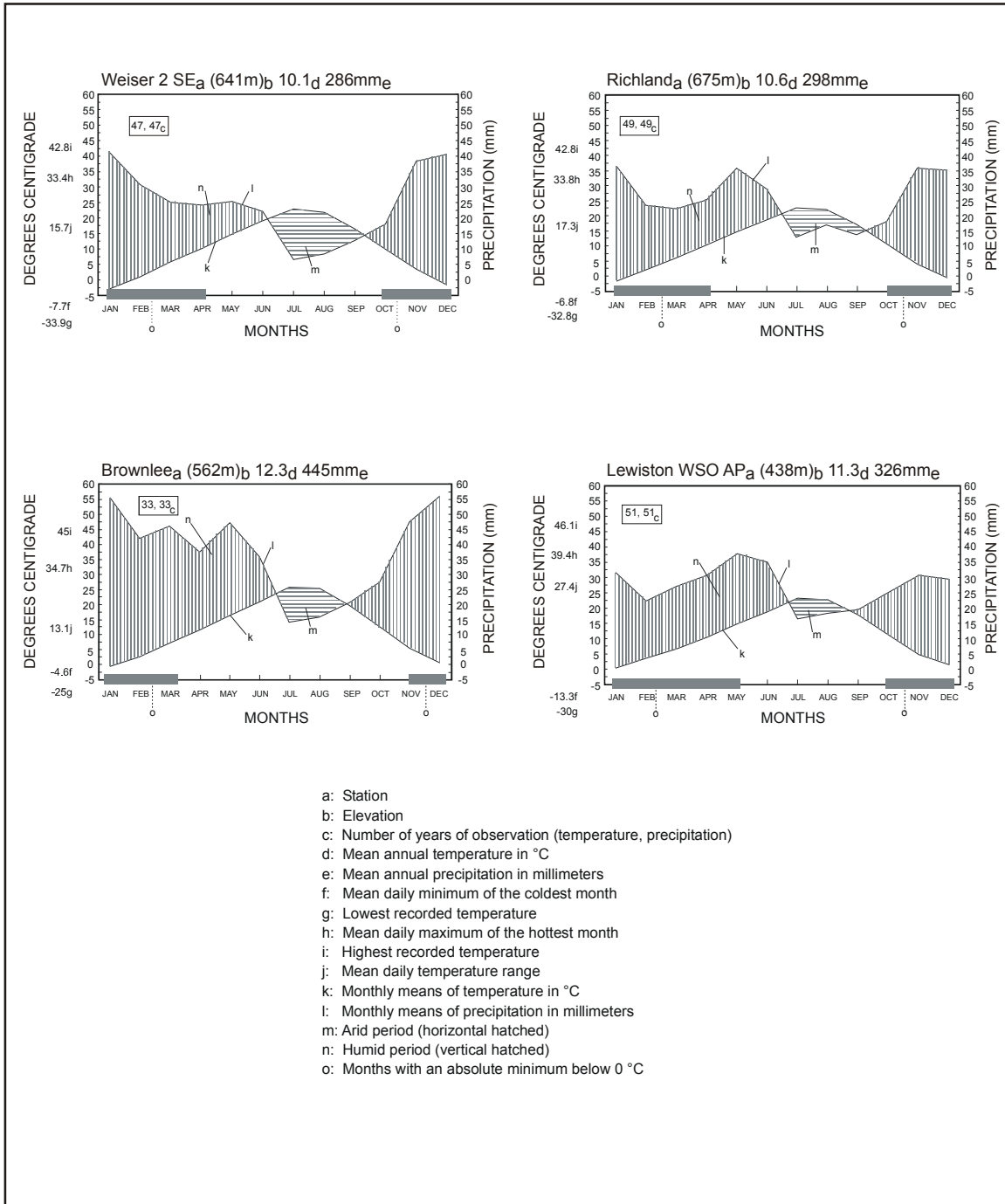


Figure 1.2. Köppen climate diagrams for the Weiser, Richland, Brownlee, and Lewiston weather stations, Hells Canyon Study Area, Idaho-Oregon border.

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CHAPTER 2: HYDROLOGIC PATTERNS AND RIPARIAN VEGETATION ALONG THE SNAKE RIVER AND RESERVOIRS OF THE HELLS CANYON CORRIDOR

2.1. Introduction

Riparian zones include areas adjacent to streams, lakes and other water bodies. These are linear landscape features that provide ecological interfaces between terrestrial and aquatic ecosystems (Naiman and Decamps 1997). Riparian zones typically support extensive and diverse vegetation since the adjacent water feature provides additional moisture that permits plant establishment and growth (Malanson 1993). Patterns of changes in water surface elevation are critical since the dynamic stage changes saturate and then expose areas that are suitable for vegetation recruitment. Appropriate water patterns subsequently support growth, expansion and reproductive development.

The contrast between riparian and upland vegetation is particularly evident in arid and semi-arid ecoregions such as along the Hells Canyon Corridor. In these areas, local precipitation is insufficient to compensate for evaporative demand. With a corresponding negative annual moisture index, the climate is too dry to support extensive forests. Consequently, trees and large shrubs are generally restricted to riparian areas, resulting in ‘emerald ribbons’ consisting of bands of riparian woodlands and shrublands that line the streams, lakes and sometimes reservoirs.

The riparian vegetation communities provide particularly rich wildlife habitats. As the photosynthetic foundation for the riparian ecosystem food-web, they also contribute substantially to the food-web of adjacent aquatic ecosystems. Additionally, the shrubs and trees provide physical habitat elements that contribute shade, shelter and breeding sites for a range of small and large animals, typically including insects and other invertebrates, and large vertebrates including birds and terrestrial mammals.

The riparian zones through the Hells Canyon corridor display these typical riparian traits and provide a vivid contrast to the upland zone as well as an ecological link between the river or reservoir and the terrestrial ecosystem. The upland zone is dominated by drought-adapted, xeric vegetation that contrasts to the more mesic and sometimes lush riparian vegetation.

Natural river-side riparian zones and artificial reservoir riparian zones share many similarities in vegetation ecophysiology and both provide rich wildlife habitats. Both river and reservoir riparian zones are absolutely dependent upon the supplemental moisture provided seasonally or continually by the adjacent water feature. The water source satisfies the moisture demands of the plants by providing water that is essential for transpiration, the water flux through the plant necessary for photosynthesis and other biochemical processes including the transport of mineral nutrients.

Recognizing the dependence of riparian vegetation on the adjacent water feature, it is logical that this vegetation will be impacted by patterns of instream flow management for river riparian zones and by patterns of reservoir stage (elevation) regulation for the reservoir zones (Malanson 1993, Jansson et al. 2000). As these relationships have become more fully recognized, current considerations for new dams or relicensing of existing dams requires analyses of potential impacts of water management pattern on riparian vegetation. Thus, the current project sought to develop and apply a methodology to predict and assess impacts of dam operations on riparian vegetation. The resulting model would be applicable both along the Hells Canyon Complex of reservoirs and along the river reach downstream from the Hells Canyon Dam. The model's development involved the quantitative analyses of recent plant distributions along the Hells Canyon corridor coupled with analyses of historical hydrologic patterns. This information would reveal the hydrogeomorphic requirements of the different plant species, both native and exotic.

The understanding of the ecophysiological linkages between water and riparian vegetation has dramatically improved over the past two decades. The generalized life history adaptations and dependencies of riparian vegetation on water originating from the adjacent streams, lakes and reservoirs have been repeatedly demonstrated (Naiman and Decamps 1997). The specialized adaptations of individual plant species continue to be investigated.

With respect to the life history traits, many riparian plants utilize the adjacent water feature as a mechanism for dispersal of propagules, a process referred to as 'hydrochory' (Nilsson et al. 1991). Types of propagules include sexually derived seeds as well as vegetative fragments (mechanically sheared or physiologically abscised branch or root segments) that can re-sprout to result in asexual propagation. Propagative dispersal typically occurs in a downstream direction along streams but may be wind-aided along lakes or reservoirs. Thus, hydrochory may occur in multiple directions along relatively stationary water bodies. Propagative dispersal by water is an effective adaptation of native plants but also provides a major mechanism for invasion by exotic weeds, of which noxious species can have severe ecological and/or economic impacts.

With respect to hydrochory, reservoirs can often interrupt this dispersal of propagules. This may hinder the transport and recruitment of native plants but it may also interrupt the expansion of invasive exotics. In the case of the Hells Canyon Complex, the extensive Brownlee Reservoir probably provides a considerable barrier to downstream dispersal of propagules. This is a favorable impact relative to weed proliferation but has the undesirable consequence of fragmenting native riparian zones (Dynesius and Nilsson 1994).

For both native and exotic species, water stage patterns are critical for the successful recruitment of new plants following dispersal of seeds or other propagules by water, wind, animal vectors or other dispersal agents. In general, obligate riparian plants tend to be ecological 'pioneers', species characterized by prolific propagule production and vigorous early growth but that are typically not competitive with established vegetation. Consequently, most obligate riparian plants can establish rapidly on appropriately moist sites that are barren of other vegetation. This same generalization is often applicable to invasive exotics. These weedy species are often characterized by prolific reproductive potential and can vigorously colonize barren areas such as those following natural or artificial disturbance.

While initial establishment is often considerable, these same riparian plant species often experience extensive mortality after establishment. This is often due to drought-stress as the riparian substrate dries out following the recession of adjacent water levels. Conversely, a favorable water regime will encourage plant growth and particularly for clonal species, expansion. Increased growth is often associated with extensive reproductive development, although the environmental influences on growth versus development are sometimes complex (and even inverted).

As the ecophysiological dependencies of riparian plants on water patterns have been investigated, a number of studies have attempted to predict vegetation responses to flow management scenarios. These include analyses by Miller et al. (2000), Mahoney and Rood (1993), Scott et al. (1993), Johnson et al. (1995), and Springer et al. (1999). The resulting models have become progressively more refined and comprehensive. Subsequent vegetation responses have proven the analyses by Miller et al. (2000) and Mahoney and Rood (1993) to be relatively accurate. Although prior modeling applications for flow scenario evaluation have been principally investigated along alluvial reaches of western North American rivers, it might be expected that scenario evaluations would be simpler and possibly more accurate for more geomorphically-inert, bedrock-confined reaches, such as the Snake River through Hells Canyon. The minimal channel change and reduced sediment and bar flux through Hells Canyon would cause less dynamic physical processes to occur over the time scale of local plant life cycles.

Based on these principles, we hypothesized a deterministic association between water pattern and plant establishment and survival. The influence of sediment and particularly surface substrate was anticipated to be important since this would influence water retention and capillarity as well as substrate permeability for root penetration. We conducted an extensive field study to test the deterministic nature of plant communities in relation to environmental parameters. Furthermore, we investigated the hydrogeomorphic requirements for the local plant species. Based on these general objectives, we formulated the following specific objectives for this study:

- 1) Collect vegetation transect data to document elevational and longitudinal occurrences of plants to provide a database for statistical and modeling analysis.
- 2) Conduct statistical and graphical analysis of relationships between vegetation, substrate and water surface elevation patterns.

The present field assessment substantially benefited from prior analyses of vegetation within the Hells Canyon Corridor. Asherin and Claar (1976) provided an earlier description of riparian vegetation and wildlife habitats along the Snake River corridor, including the Hells Canyon Corridor. The extensive analysis by Holmstead (2001) included the riparian corridor in addition to upland landscapes and described the plant communities through the study corridor. Holmstead (2001) also provided a brief literature review relative to botanical inventories of the Hells Canyon corridor including recognition of the extensive riparian investigation by Crowe and Clausnitzer (1997). Krichbaum (2000) focused on the distribution of noxious and invasive exotics and included broader plant inventories. The studies by Dixon and Johnson (1999) and Johnson et al. (1995) investigated vegetation along reaches upstream from the Hells Canyon Corridor and included aspects contributing to the understanding of autecological and

hydrogeomorphic interactions. Some other reports relevant to regional plants, plant communities, and historical impacts are discussed in our prior report associated with the Hells Canyon project (Blair et al. 2001).

2.2. Methods

2.2.1. Methods for Summarizing Hydrologic Data

The Idaho Power Company has maintained a continuous record of water levels for Brownlee, Oxbow and Hells Canyon Reservoirs (1958–Present). Data from these water level recorders were summarized in relation to a) annual minimum, mean and maximum water levels, and b) seasonal water level fluctuations. Three time periods were selected for comparative analyses of water level fluctuations following completion of Hells Canyon Dam, including: a) 1970–74, b) 1984–89, and c) 1994–99. A time interval of five years was chosen, because Brownlee Reservoir has been operated since 1994 to fill and draw-down twice a year. The periods of 1970–74 and 1984–89 were chosen to reflect operations in different decades, and hence different climatic conditions following the filling of Hells Canyon Reservoir.

The US Geological Survey has maintained a long-term record of stage and discharge for the Snake River at Weiser, Idaho (1911–Present; Figure 2.1.) and Hells Canyon Dam (1967–Present). Data from these river gages were summarized in relation to a) annual minimum, mean and maximum discharge and b) seasonal flow patterns. Several time intervals were selected to span a series of flow regimes prior to and post-completion of the Hells Canyon Hydroelectric Complex. At the Weiser Gage, flows were summarized for the following time intervals: a) 1911–1921 (flows prior to extensive water development in the Snake River Basin), b) 1948–1958 (flow regime just prior to completion of Brownlee Dam), and c) 1990–99 (flow regime during the latest decade; Figure 2.2.). In order to compare flow regimes immediately above and below the project reservoirs with dam operations, the following intervals were selected for comparative analysis of the Weiser and Hells Canyon reaches of the Snake River: a) 1970–74, b) 1984–89, and c) 1994–99 (Figure 2.3.). These intervals are the same periods selected for comparing water level fluctuations along the reservoir reaches.

2.2.2. Vegetation Sampling Methods

Patterns of plant distribution were quantified using a series of permanent transects established along riverbanks and shorelines during the 1998, 1999 and 2000 growing seasons. Transects were located within the study corridor using a stratified-random sampling scheme. The study corridor was divided into 0.2-mile segments, with one segment randomly selected per river mile. Transects were positioned in relation to geomorphic settings that were representative of the particular shoreline segment. In cases of diverse and complex geomorphic features, more than one transect was located within a given sample segment. On the basis of these selection criteria, 92 transects were located along reservoir reaches, 47 along the three reaches of Brownlee Reservoir, and 45 along the three reaches of the Oxbow and Hells Canyon reservoirs. There were 93 transects along riverine reaches of the Snake River with 22 positioned along the Weiser reach

and 71 through the Hells Canyon reach below Hells Canyon Dam. Overall this resulted in a density of 1.15 transects per ‘river’ mile along the study corridor.

2.2.2.1. Belt-transects

Plant distributions along riverbanks and shorelines were sampled using belt-transects. Each belt-transect was established perpendicular to the shoreline and extended upslope through the zones of riparian vegetation and into the upland shrub-steppe habitats (Figure 2.4.). Given the steep slopes of this study corridor, belt-transects were short, ranging from about 10 to 60 m in length. Areas dominated by herbaceous plants were sampled using 1 m x 1 m quadrats placed at 1 m intervals along the transect (quadrats were generally positioned on the upstream side of the transect line). Larger quadrats were used to sample areas dominated by shrubs (2 m x 4 m quadrats) and trees (5 m x 10 m quadrats).

A permanent metal stake engraved with an identification number was driven into the top of each transect. A transit level was used to determine the relative elevation (± 0.1 cm) of the top corner of each quadrat along each transect. The geographic location at the top (at the stake) and bottom (at the current water surface) of each transect was recorded using a Trimble GPS Pathfinder ProXRS (sub-meter resolution, Trimble Navigation Inc., USA). The date and exact time of day for each measurement was noted. These methods follow general sampling protocols of Mueller-Dubois and Ellenburg (1974), Goldsmith et al. (1986), Johnson et al. (1987, 1992, 1995), Scott et al. (1993), and Auble et al. (1994). The GPS coordinate of the water surface level benchmark was later linked with elevation data derived from the reservoir water surface database (Idaho Power Co, Boise, ID) or the river hydraulics model calibrated to continuous-recording pressure transducers (Acoustic Doppler Current Profiler) along the Hells Canyon reach of the Snake River. This combination of elevational information allowed the assessment of relationships between species distributions and the patterns of annual and seasonal water levels.

All vegetational species present in each quadrat were identified according to the nomenclature of Hitchcock and Cronquist (1991) and Whitson et al. (1996). The proportion of cover relative to the size of the given quadrat was estimated for each species. These estimates of plant cover were converted to an octave scale for all subsequent analyses to minimize subjective sampling error, while preserving fine-scale differences at low cover values. The octave classes that were used in this study are: 0 (0% cover), 1 (1%), 2 (2–4%), 3 (5–9%), 4 (10–18%), 5 (19–35%), 6 (36–72%), 7 (73–100%); with mid-points of each coverage class (0, 1, 3, 7, 14, 27, 54, and 86.5%, respectively) used in subsequent data analyses. Stem counts and age-class determinations were also obtained for dominant trees and shrubs.

Quadrats were classified according to their position along the elevation/inundation gradient of reservoir shorelines and riverbanks as: 1) barren reservoir/streamside zone, 2) obligate riparian zone, 3) facultative/transitional riparian zone, or 4) upland zone. Surface substrates were classified for each quadrat into one of four categories: 1) fine–fine sediment (sand, silt, or clay), 2) fine–cobble–coarse surface (gravel, cobbles) with a subsurface of fines, 3) cobble–coarse surface (gravel, cobbles, small boulders) without fines below the surface layer of rock, and 4) large boulders and bedrock. A visual classification of these substrate classes was recorded for each quadrat.

2.2.2.2. Data Analyses

Patterns of vegetation change along the coenoclines of riverbanks and reservoir shorelines were analyzed using direct gradient analysis and canonical correspondence analysis (CCA) (Johnson et al. 1987, 1992, 1995, Scott et al. 1993, Auble et al. 1994). Distribution patterns of major life forms or physiognomic types (trees, shrubs, and annual and perennial forbs and grasses) along riverbanks and shorelines were first assessed using direct gradient analysis. Graphs were drawn showing the distributions of plant life forms from upland shrub-steppe habitats to the water's edge. The relative cover index and average percent cover of different life forms was plotted in a similar fashion. These analytical methods follow those of Johnson et al. (1987, 1992, 1995).

Multivariate relationships between plant species and environmental variables were explored using canonical correspondence analysis (CCA). Twelve different environmental variables were analyzed: 1) mean high water mark, 2) full pool elevation, 3) mean low water mark, 4) mean annual water surface elevation, 5) number of days inundated per year, 6) date of first flooding, 7) date of last flooding, 8) number of times inundated per year, 9) maximum duration of inundation, 10) maximum duration of dry conditions, 11) slope and 12) surface substrates. (1958–1999, USGS and IPC hydrologic records) (Table 2.1.). These analyses were conducted using PC-ORD (Version 4.0, MJM Software, Gleneden Beach, OR), and CANOCO (Version 4.0, Ithaca, NY, ter Braak and Smilauer 1998), which are comprehensive software packages for multivariate analysis of vegetation and environmental data. Monte Carlo simulations were performed on all CCA analyses ($n = 100$, $P \leq 0.01$). CCA groups species and/or quadrats into distinctive clusters and spatially arrays these clusters in relation to environmental variables. As a result, CCA is useful in evaluating multivariate relationships within and between species, quadrats, transects, and environmental data (i.e. species abundance, seasonal water levels, substrate and topographic variables).

Plant assemblages were identified using Two-Way INdicator SPecies Analysis (TWINSPAN, Cornell Labs, Ithaca, NY; PC-ORD Version 4.0 Software, MJM Software Design, Gleneden Beach, OR). Prior to conducting TWINSPAN analyses, vegetation data was aggregated according to a) study reach (Brownlee, Oxbow/Hells Canyon and the Weiser and Hells Canyon reaches of the Snake River), and b) riverbank or shoreline elevation zone (i.e., sites above vs. sites below full pool/mean high water mark). Plant assemblages were derived by aggregating/analyzing quadrat data collected at similar shoreline/riverbank elevations for all transects within a given study reach.

A list of species for each study reach was developed by tallying all species found along sample transects. The most common species are summarized by reach in Table 2.2 and Appendix 2.1.

2.3. Results

2.3.1. Water Level Fluctuations along Reservoir Shorelines

Annual and seasonal water-level fluctuations vary significantly across the three study reservoirs (Figures 2.5. to 2.10.). This variation is related to differences in operational strategy, whereby Brownlee is a storage reservoir and both Oxbow and Hells Canyon reservoirs re-regulate flow

releases from Brownlee Dam. Under current operations, there are large seasonal declines in the water levels of Brownlee Reservoir (Figures 2.5. and 2.6.); but given its large size, there are only slight diurnal declines. In contrast, both Oxbow and Hells Canyon reservoirs are limited to diurnal water level fluctuations (Figures 2.7. to 2.10.).

Annual water level declines for Brownlee reservoir occasionally exceed 80 to 90 feet (Figure 2.5.), with the highest draw-downs related to a) the filling of Hells Canyon Reservoir in the mid 1960s, and b) climatic conditions and maintenance activities in the 1970s and 1990s. Daily water level fluctuations in both Oxbow and Hells Canyon reservoirs are generally on the order of only 2 to 6 ft, (Figures 2.7. to 2.10.).

Seasonal water level declines for Brownlee have changed significantly over the last few decades (Figure 2.6.). In the 1970s and 1980s, there was a single draw-down in water levels, whereas a double filling and draw-down was been initiated in the late 1990's to assist in the management of native salmon stocks (Figure 2.6.). The magnitudes of these seasonal draw-downs were much more extreme in the 1970s and 1990s.

2.3.2. Plant Distribution along Reservoir Shorelines

Patterns of plant distribution and community structure have been closely correlated with seasonal fluctuations in water levels along reservoir shorelines. Different water levels have resulted in significant differences in the composition and structure of shoreline plant communities between Brownlee reservoir (seasonal storage with extensive draw-downs) and Oxbow/Hells Canyon reservoirs (re-regulating “run of river/Brownlee” with diurnal stage fluctuations).

2.3.2.1. Brownlee Reservoir - Main (BM; River mile 326.0 to 284.5)

Grasses and Forbs

Grasses and forbs were the most common life forms found along the shorelines of Brownlee reservoir. Annual grasses and forbs were also the most common plants found below full pool (Figure 2.11.). Annual grasses, such as cheatgrass (*Bromus tectorum*) and medusa-head rye (*Taeniatherum caput-medusae*), were common above and below full pool elevations, whereas annual forbs dominated barren substrates below full pool (Figures 2.11., 2.12b., 2.13b.). Common annual forbs included cocklebur (*Xanthium strumarium*), Purslane (*Portulaca oleracea*), and tumble pigweed (*Amaranthus alba*) (Table 2.2., Appendix 2.1). In these mainly barren areas, lower water levels during both the late winter and summer months enabled annual plants to produce two distinct generations each year. However, the average plant cover below the full pool level was very low ($\leq 7\%$), relative to transitional and upland habitats (10 to 50%, Figure 2.13b.). The soil and substrate affinities of grasses and forbs were similar (Figure 2.14.); with higher incidence and coverage on fine to fine-cobble substrates. Given these hydrologic and substrate affinities, annual species were a major component of upland, barren, and facultative shoreline habitats (Figures 2.11. to 2.15., n = 200 to 730).

Perennial grasses and forbs were common along Brownlee Reservoir at elevations above full pool (Figure 2.11.), and only occasionally were the seedlings of perennial species observed within the draw-down zone. The relative coverage of perennial species was comparable to

annuals in upland to facultative habitats (5% to 50%, Figure 2.12b.). Average plant cover was significantly higher in these non-inundated habitats relative to barren zones below full pool (Figure 2.13b.). The soil and substrate affinities of perennial grasses and forbs were similar to annual species (Figure 2.14.). Overall, perennial grasses and forbs were a significant component of upland and facultative shoreline habitats (Figures 2.11. to 2.15., n = 38 to 147). Non-vascular plants (lichens and mosses) were also common on steep, rocky slopes throughout the reach (Figures 2.14., 2.15.).

Trees and Shrubs

Trees and shrubs were uncommon along the shorelines of Brownlee Reservoir. When present, they were rooted in either facultative or upland habitats (Figures 2.11., 2.12b., 2.13b., n = 102). Common species included false indigo (*Amorpha fruticosa*), and sagebrush (*Artemisia tridentata*) (Table 2.2., Appendix 2.1). During the latter stages of the growing season, some tree and shrub seedlings were occasionally found to have germinated below full pool. However, these seedlings would fail to survive prolonged inundation upon the return to full pool conditions in early summer or during winter months. In most cases, overhanging branches of trees and shrubs growing along steep shorelines accounted for the woody plant coverage recorded at elevations below full pool (Figures 2.11c., 2.12b., 2.13b.). The substrate affinities of trees and shrubs were similar to those observed for forbs and grasses (Figure 2.14., n = 102).

Correlations with Environmental Variables

Plant distributions along Brownlee Reservoir were strongly correlated with all hydrologic variables and weakly correlated with slope or substrate properties. The occurrence of different species in shoreline environments was correlated with: 1) mean high water mark, 2) mean annual water surface, 3) mean low water mark, 4) full pool elevation, 5) number of days inundated/year, 6) number of times inundated/year, 7) maximum duration of inundation/year, 8) maximum duration of exposed dry conditions/year, and 9) last day of the year inundation occurred ($r = 0.872$ to 0.943 , Table 2.3.). As expected, there were high intra-set correlations among water-surface variables. Since the highest correlation was related to full pool elevation, full pool was used as the primary hydrologic variable in subsequent CCA analyses (Table 2.3.). There was a strong species versus environment correlation ($r = 0.955$) for this data set, yet the percent of the variance explained by each axis was low (1.5 to 4.0%, Table 2.3.).

A CCA ordination of vegetated quadrats for all Brownlee transects is shown in Figure 2.16. There are two distinct groups within this large array of quadrats. Quadrats located on the right represent barren, drawn-down sites exposed during seasonal water level declines. The smaller group to the left is primarily quadrats found above full pool. Thus, drier sites were arrayed to the left and sites exposed to long-term inundation on the right. The length of axes for different environmental variables correlated with Axis 1 shows the relative strength of their correlations with vegetation patterns. Slope-related effects were correlated to the second axis ($r = 0.469$, Table 2.3.). Sites with steeper slopes are arrayed on the upper half of Figure 2.16., whereas more gradually sloping sites are found toward the bottom of Axis 2.

The CCA ordination of plant species in relation to different environmental variables is shown in Figure 2.17. Annual and perennial species growing in drier shoreline conditions are arrayed to the left, whereas those annual species adapted to growing conditions limited by periodic

inundation are found on the right (Axis 1, Figure 2.17.). Among the large number of annuals found in this reach (Table 2.2., Appendix 2.1), annual grasses were found primarily in drier upland and facultative sites, whereas annual forbs dominated barren draw-down sites (Figure 2.11.).

Composition of Shoreline Plant Communities

Several plant assemblages were identified for the shorelines of Brownlee Reservoir (Table 2.4.). More than one assemblage was commonly associated with the following shoreline habitats: 1) barren zone (\ll full pool), 2) obligate riparian zone (\leq full pool), 3) facultative/transitional zone (\geq full pool), and 4) upland zone ($>$ full pool) (Table 2.4., Figure 2.18.). Grassland and sagebrush communities dominated reservoir shorelines, with a highly fragmented distribution of other plant assemblages.

Common cocklebur (*Xanthium strumarium*) and Purslane/Tumble Pigweed (*Portulaca oleracea/Amaranthus alba*) were the most common assemblages found in barren draw-down zones (Table 2.4.). Some species commonly associated with these assemblages included: *Amaranthus retroflexus*, *Echinochloa crus-galli*, *Epilobium paniculatum*, *Euphorbia glyptosperma*, and *Poa annua* (Table 2.2., Appendix 2.1). These annual-dominated assemblages were noted for low levels of plant cover ($\leq 7\%$) relative to other shoreline habitats (Figure 2.13b.).

Obligate riparian habitats were uncommon in this reach. False indigo (*Amorpha fruticosa*) and reed canarygrass (*Phalaris arundinacea*) were the most common assemblages in obligate riparian zones (Table 2.4.). These assemblages were widely distributed, yet highly fragmented in their distribution along reservoir shorelines. In some cases, these assemblages were limited to isolated patches of 1–2 individuals or clonal clumps at full pool elevation. Typically, reed canarygrass was limited to areas where pockets of fine sediments had accumulated near full pool. When present, coverage values for these assemblages were high, ranging from 30 to $>50\%$ (Figure 2.13b.). Annual grasses, such as *Bromus tectorum*, *B. japonicus* and *Taeniatherum caput-medusae* were also associated with these assemblages (Table 2.2., Appendix 2.1).

False indigo (*Amorpha fruticosa*) was the most common assemblage found in facultative/transitional zones (Table 2.4.). Coverage values for this woody assemblage were relatively high (30 to 40%, Figure 2.13b.). Associated species included annual and perennial grasses including *Agropyron spicatum*, *Bromus tectorum*, *B. japonicus*, *Poa secunda* and *Taeniatherum caput-medusae*, and annual and perennial forbs such as *Convolvulus arvensis*, *Helianthus annuus*, *Lactuca serriola*, *Lepidium latifolium*, and *Melilotus officinalis* (Table 2.2., Appendix 2.1).

Upland plant assemblages were composed of grasses and shrubs, such as big sagebrush (*Artemisia tridentata*) and mixed grass/forb assemblages (Table 2.4.). These upland assemblages would either extend downslope to full pool or were slightly upslope of the facultative or obligate riparian assemblages. A diverse number of annual and perennial grasses and forbs were associated with these assemblages (Table 2.2. and Appendix 2.1 lists the grasses and forbs commonly observed in this reach).

2.3.2.2. Main Oxbow/Hells Canyon Reservoirs (OM / HM; River Mile 284.5 to 241.1)

Grasses and Forbs

Grasses and forbs were abundant along the shorelines of Oxbow (Figure 2.19.) and Hells Canyon reservoirs (Figure 2.20.). On Oxbow Reservoir, annual grasses (i.e. *Bromus tectorum*, *Bromus japonicus* and *Taeniatherum caput-medusae*) were more common than perennial grasses (*Agropyron spicatum* and *Festuca idahoensis*), whereas perennial forbs were more dominant than annual forbs (Figure 2.19., Table 2.2., Appendix 2.1). Similar patterns were observed for Hells Canyon reservoir, although differences between annual and perennial species were less pronounced (Figure 2.20.). Diurnal surface water fluctuations (+/- 1 to 2 m) combined with the absence of pronounced seasonal declines in water levels have resulted in abundant grass and forb cover near full pool (Figures 2.21., 2.22.). However, the average coverage by grasses and forbs was lower (5% to 25%) than woody plants (20% to 75%) (Figure 2.22.). Soil and substrate affinities ranged from fine to coarse substrates (Figure 2.23.); similar to patterns observed for Brownlee reservoir (Figures 2.14.). Given these hydrologic and substrate affinities, perennial species were more abundant than annual species in shoreline habitats (Figures 2.19.–2.22.). Non-vascular vegetation (lichens and mosses) was also more abundant on the rocky slopes of Hells Canyon than along either Oxbow or Brownlee reservoirs (Figures 2.23., 2.24.).

Trees and Shrubs

In contrast to Brownlee reservoir, trees and shrubs were relatively abundant along the shorelines of Oxbow and Hells Canyon reservoirs (Figures 2.19c., 2.20c., Table 2.2., Appendix 2.1). Common woody species included: false indigo (*Amorpha fruticosa*), Himalayan blackberry (*Rubus discolor*), netleaf hackberry (*Celtis reticulata*), poison ivy (*Toxicodendron radicans*), and sandbar willow (*Salix exigua*). Woody exotics were highly visible, yet less common, and included green ash (*Fraxinus pennsylvanica*), mulberry (*Morus alba*), Russian olive (*Elaeagnus angustifolia*), Siberian elm (*Ulmus pumila*) and walnut (*Juglans regia*). Woody plants were limited to upland and facultative habitats at elevations near full pool (Figures 2.19.–2.22.). The age of trees in this reach ranged from 18 years for Siberian elm to more than 43 years for netleaf hackberry (Table 2.5.). Relative cover indices (Figure 2.21.) and average cover per quadrat (Figure 2.22.) were higher for woody species (20% to 75%) than for forbs and grasses (5% to 25%). Substrate affinities were diverse, ranging from fine soils to coarse cobbles and boulders (Figure 2.23.).

Correlations with Environmental Variables

Plant distribution was weakly correlated with hydrologic variables, slope and substrate properties. Distribution patterns were correlated to: 1) full pool elevation, 2) number of days inundated/year, 3) number of times inundated/year, 4) maximum duration of inundation/year, 5) maximum duration of exposed dry conditions/year, and 6) last day of year inundation occurred ($r = 0.399$ to 0.617 , Table 2.6.). The slope of reservoir shorelines showed a slightly higher correlation ($r = 0.624$) than full pool elevation ($r = 0.617$). There was a moderate species: environment correlation ($r = 0.840$) for this data set, and the percent of the variance explained by each axis was low (1.3 to 2.3%, Table 2.6.).

A CCA ordination of vegetated quadrats for Oxbow and Hells Canyon transects is shown in Figure 2.25. Within this array of quadrats, there was not a clustering of quadrats into distinct groups. In general, quadrats located toward the left represent sites exposed to strong, diurnal water level fluctuations. Quadrats on the right hand side of the figure were above full pool. Thus, drier sites are arrayed to the right and sites exposed to repeated inundation toward the left (Axis 1, Figure 2.25.). Sites with steep slopes are found on the upper half of the figure, whereas more gradually sloping sites are found toward the bottom (Axis 2, Figure 2.25.). The relatively short length of environmental axes shows their moderate to weak correlations with shoreline vegetation patterns.

Species distribution in relation to the different environmental variables is shown in Figure 2.26. With some exceptions, species adapted to drier soils are arrayed to the right, and species exposed to repeated inundation are found on the left (Axis 1, Figure 2.26.). Diurnal water level fluctuations combined with the absence of a significant seasonal decline in reservoir water levels has resulted in a strong convergence in the distribution of species near full pool (Figures 2.19., 2.20.).

Composition of Shoreline Plant Communities

Plant assemblages along the shorelines of Oxbow and Hells Canyon Reservoirs were diverse and highly variable (Table 2.7.). Diurnal inundation of shoreline environments has promoted a convergence in the distribution of species near full pool. With the exception of woody-dominated assemblages, this convergence in plant distribution somewhat confounded the identification of distinct assemblages within shoreline environments. Approximately three to five different assemblages were associated with the following shoreline vegetation zones/habitat types: 1) obligate riparian zone (\leq full pool), 2) facultative/transitional zone (\geq full pool), and 3) upland zone ($>$ full pool) (Table 2.7., Figure 2.27.).

Barren zones below full pool were largely devoid of vegetation in these reservoir reaches. Repeated inundation by diurnal water fluctuations has prevented the establishment of plants in the draw-down zones below these “re-regulating” dams. Lower surface water levels would expose a thin band (1-2 m) of barren rock and cobble.

Obligate riparian assemblages were primarily limited to the alluvial fans of side-tributaries. The shallower slopes and accumulated fines in these confluence areas supported riparian forbs and woody plants adapted to moist soil conditions. Some common obligate riparian assemblages included: coyote willow (*Salix exigua*), false indigo (*Amorpha fruticosa*), reed canarygrass (*Phalaris arundinacea*), scouring rush (*Equisetum laevigatum*) and yellow flag (*Iris pseudacorus*) (Table 2.7.). These assemblages were somewhat monotypic, with high levels of coverage ($> 70\%$) by the locally dominant species. A large number of different grass and forb species were associated with these plant assemblages (Table 2.2., Appendix 2.1).

Woody plant assemblages dominated facultative/transitional shoreline environments (Table 2.7.). False indigo (*Amorpha fruticosa*), Himalayan blackberry (*Rubus discolor*), netleaf hackberry (*Celtis reticulata*), poison ivy (*Toxicodendron radicans*) and mixed woody exotics (*Eleagnus angustifolia*, *Fraxinus pennsylvanica*, *Juglans regia*, *Morus alba*, *Ulmus pumila*) were some of the more common assemblages identified in this reach (Table 2.7.). These woody-dominated

assemblages had a highly scattered and fragmented distribution along reservoir shorelines. Patterns of plant coverage varied from dense stands (coverage > 80%) with a limited understory to open canopies (coverage < 50%) with a diverse understory of upland species. Some associated species included: a broad range of annual and perennial grasses (*Agropyron spicatum*, *Bromus tectorum*, *B. japonicus*, *Poa secunda* and *Taeniatherum caput-medusae*), and forbs (*Artemisia ludoviciana*, *Cichorium intybus*, *Convolvulus arvensis*, *Epilobium paniculatum*, *Helianthus annuus*, *Lactuca serriola*, *Melilotus officinalis* and *Plantago lanceolata*). Broad-leaved pepperweed (*Lepidium latifolium*), a noxious species, was also commonly associated with this assemblage (Table 2.2., Appendix 2.1).

Upland habitats were largely composed of grasses and shrubs, such as big sagebrush (*Artemisia tridentata*), serviceberry (*Amelanchier alnifolia*) and mixed grass/forb assemblages (Table 2.7.). With the exception of steep side slopes (> 35% slope, where upland species commonly inhabited shoreline environments), these upland assemblages were just upslope of the facultative or obligate riparian assemblages. A diverse number of annual and perennial grasses and forbs were associated with these upland assemblages (Table 2.2. and Appendix 2.1 list the common forbs and grasses in this reach.)

2.3.3. Riparian Ecology of Transitional Lotic-Lentic Reaches

The transition from free-flowing reach to reservoir impoundment is associated with a significant shift in environmental conditions governing the establishment and survival of riparian and shoreline plants. The seasonal water fluctuations of reservoirs regulate patterns of inundation. Thus, the aerial extent of this transition zone can vary significantly during the course of a growing season. Over a relatively short distance, there can be significant longitudinal variation in riparian vegetation patterns. In the Hells Canyon Hydroelectric Complex, there are three major lotic-lentic transition zones: 1) Headwaters of Brownlee Reservoir, 2) Confluence of the Powder River with Brownlee Reservoir and the 3) Oxbow Bypass (a special case of fluctuating backwater impoundments, periodic spillway releases, and storm-related overflows).

2.3.3.1. Brownlee Reservoir - Headwater (BH; River Mile 342.9 to 326.0)

The riparian vegetation found in the transition zone from the Weiser reach to Brownlee Reservoir shared attributes unique to both reaches. The upper portion of this section was similar to the Weiser reach of the Snake River, whereas the lower portion was more comparable to the shoreline vegetation of Brownlee Reservoir.

Grasses and Forbs

Grasses and forbs were a significant component of upland and shoreline communities in this headwater reach (Figure 2.28.). Similar to reservoir reaches, annual grasses and forbs were more common than perennial species. However, there was greater species diversity among annual grasses than observed along the shorelines of Brownlee Reservoir. Common grasses included annual bluegrass (*Poa annua*), barnyard grass (*Echinochloa crus-galli*), Heleochloa (*Heleochloa alopecuroides*) and witchgrass (*Panicum capillare*) (Table 2.2., Appendix 2.1). In general, these species were adapted to moister soil conditions. Similar to the draw-down zones of Brownlee, annual forbs included *Amaranthus albus*, *Portulaca oleracea*, and *Xanthium strumarium*. The

relative cover of annuals was higher in zones 1-2 m above and 2-10 m below full pool. The average cover for annuals per quadrat was significantly lower than for perennial species (Figures 2.12a., 2.13a.). Perennial pepperweed (*Lepidium latifolium*), listed as noxious in both Idaho and Oregon, was common in this reach (Table 2.2., Appendix 2.1). Apparently since sediment deposition is a more active process in transition zones, many species were found growing on finer substrates (Figure 2.14.).

Trees and Shrubs

Woody species were more abundant along the headwater reach than along the main Brownlee Reservoir (Figures 2.11., 2.28., Table 2.2., Appendix 2.1), and formed a series of scattered riparian stands. The most common species included: false indigo (*Amorpha fruticosa*), European willows (*Salix alba* & *Salix rubens*), peachleaf willow (*Salix amygdaloides*), sandbar willow (*Salix exigua*), and salt cedar (*Tamarix ramosissima*). Of these, salt cedar was the most dominant woody species in this reach. Salt cedar seedlings were widespread (50 to 1500/m²) along shorelines and islands, with mature trees forming large, dense stands near Farewell Bend. The relative cover of woody species was highest near full pool, with significantly higher coverage values than grasses and forbs (Figures 2.12a., 2.13a.). The age of trees in this reach ranged from 9 years for salt cedar to 15–20 years for European willow and Russian olive (Table 2.5.).

Correlations with Environmental Variables

Plant distribution along the headwater reach of Brownlee Reservoir was strongly correlated with slope and several hydrologic variables. Distribution patterns were correlated to: 1) number of days inundated/year, 2) max duration of inundation/year, 3) max duration of exposed dry conditions/year, 4) last day of year inundation occurred, 5) full pool and 6) mean annual water surface ($r = 0.687$ to 0.730 , Table 2.7.). The relationship to shoreline slope was also fairly significant ($r = 0.687$, Table 2.8.). There was a strong species versus environment correlation ($r = 0.904$), yet the percent of the variance explained by each axis was low (2.6 to 4.8%, Table 2.8.).

A CCA ordination of vegetated quadrats for Brownlee headwater transects is shown in Figure 2.29. Within this array of quadrats, there was moderate clustering of quadrats into distinct groups. In general, quadrats located toward the right represent barren sites exposed to seasonal inundation and reservoir draw-downs. Quadrats on the left side of the figure were above full pool. Thus, drier sites are arrayed to the left and sites exposed to repeated and long-term inundation are toward the right (Axis 1, Figure 2.29.). Sites with steep slopes are found on the upper half of the figure, whereas more gradually sloping sites are found toward the bottom (Axis 2, Figure 2.29.). The relatively long length of environmental axes shows the relative strength of correlations between environmental variables and vegetation patterns.

The species distribution in relation to the different environmental variables is shown in Figure 2.30. With some exceptions, species adapted to drier soils are arrayed to the left, and species exposed to inundation and seasonal draw-downs are found on the right (Axis 1, Figure 2.30.). Seasonal decline in reservoir water levels have resulted in a strong convergence of species near full pool, particularly of woody plants (Figure 2.28.).

Composition of Shoreline Plant Communities

The species composition in the headwaters of Brownlee Reservoir was intermediate to the riverbanks of Weiser reach and Brownlee reservoir shorelines. Different assemblages were associated with the following shoreline vegetation zones/habitat types: 1) barren zone (< full pool), 2) obligate riparian zone (\leq full pool), 3) facultative/transitional zone (\geq full pool), and 4) upland zone (> full pool) (Table 2.9., Figure 2.31.).

Common cocklebur (*Xanthium strumarium*) and Purslane/Tumble Pigweed (*Portulaca oleracea/Amaranthus alba*) were the most common assemblages found in barren draw-down zones (Table 2.9.). Some species commonly associated with these assemblages included: *Echinochola crus-galli*, *Euphorbia glyptosperma*, *Panicum capillare* and *Poa annua* (Table 2.9., Appendix 2.1). These annual-dominated assemblages were noted for low levels of plant cover (\leq 20%) relative to other shoreline habitats (Figure 2.13a.).

Obligate riparian habitats were relatively common in this reach. False indigo (*Amorpha fruticosa*), coyote willow (*Salix exigua*) and saltcedar (*Tamarisk* complex) were the most common assemblages in obligate riparian zones (Table 2.9.). These assemblages were widely distributed, with coverage values ranging from 20 to >50% (Figure 2.13a.). Annual grasses, such as *Bromus tectorum*, *Panicum capillare* and *Poa annua* were also associated with these assemblages (Table 2.9., Appendix 2.1).

Saltcedar (*Tamarisk* complex) was the most common assemblage found in facultative/transitional zones (Table 2.8.). Associated species included false indigo (*Amorpha fruticosa*) and mixed woody exotics, such as Russian olive. Annual grasses included *Bromus tectorum*, *Echinochola crus-galli*, *Panicum capillare* and *Poa annua* and annual and perennial forbs such as *Amaranthus albus*, *Convolvulus arvensis*, and *Lepidium latifolium* (Table 2.2., Appendix 2.1).

Upland plant assemblages were composed of grasses and shrubs, such as big sagebrush (*Artemisia tridentata*) and mixed grass/forb assemblages (Table 2.9.). These upland assemblages would either extend downslope to full pool or were slightly upslope of the facultative or obligate riparian assemblages. A diverse number of annual and perennial grasses and forbs were associated with these assemblages (Table 2.2. and Appendix 2.1 lists the grasses and forbs commonly observed in this reach).

2.3.3.2. Brownlee Reservoir - Powder River Arm (BP; River Mile 295.7)

The confluence of the Powder River with Brownlee Reservoir (the Powder River Arm of Brownlee Reservoir) is a zone of extensive sediment deposition. Water levels are shallow at full pool, exposing large mudflats during lower reservoir water levels. These conditions favor annual and perennial species adapted to fine, moist substrates. At lower water levels, exposed mudflats provide a unique habitat for waterfowl and shorebirds.

Grasses and Forbs

Grasses and forbs dominate the flora of the Powder River Arm (Figure 2.32.). Annual species comprise a large proportion of the local flora, common species include: annual bluegrass (*Poa annua*), barnyard grass (*Echinochola crus-galli*), Heleochloa (*Heleochloa alopecuroides*) and

witchgrass (*Panicum capillare*) (Table 2.2., Appendix 2.1). Of these, *Poa annua* was the most abundant. Similar to the draw-down zones of the Main Brownlee Reservoir, annual forbs included *Amaranthus albus*, *Portulaca oleracea* and *Xanthium strumarium* (Table 2.2.), with purslane being the most common. Annual species dominated the exposed mudflats at elevations down to 10 meters below full pool (Figure 2.32., 2.12c., 2.13c.). Common perennial species included: reed canarygrass (*Phalaris arundinacea*), teasel (*Dipsacus sylvestris*), and water smartweed (*Polygonum amphibium*). Water smartweed was found almost exclusively in saturated soils at elevations 3 to 5 meters below full pool, whereas reed canarygrass and teasel was found near full pool (Figures 2.32., 2.12c., 2.13c.). Plants growing on these exposed mudflats had a strong affinity for fine soil texture classes (Figure 2.14.).

Trees and Shrubs

Woody species were less abundant than herbaceous species on the Powder River Arm, and their distribution was limited to elevations near full pool (Figures 2.32., 2.12c., 2.13c.). Willows (*Salix exigua* and *S. amygdaloides*) were the predominant woody species found in this reach (Table 2.2., Appendix 2.1), although black cottonwood (*Populus trichocarpa*) was visible in the distance along a nearby, free-flowing reach of the Powder River. The relative and average cover of willows near full pool was higher than for herbaceous species (Figure 2.12c., 2.13c.), and their substrate affinities were limited to fine soil texture classes (Figure 2.14.).

Correlations with Environmental Variables

Plant distribution was closely correlated to the timing and duration of inundation (Table 2.10.). Distribution patterns were strongly correlated with 1) number of days inundated, 2) last day of the year inundation occurred, 3) maximum length of inundation, 4) average number of days inundated per year ($r = 0.749$ to 0.989 , Table 2.10.) and only weakly correlated with full pool conditions ($r = 0.533$). Given the dominance of shallow, gradual slopes and finely textured substrates in this reach, there was no correlation with slope or substrate texture. There was a high species versus environment correlation ($r = 0.994$) for this data set, and the percentage of the variance explained by each axis was also relatively high (8.7 to 15.9%, Table 2.10.).

A CCA ordination of sample quadrats and species is shown in Figures 2.33. and 2.34. Upland quadrats are arrayed to the right and facultative, obligate and barren quadrats toward the left side of the diagram (Axis 1, Figure 2.33.). Quadrats subject to frequent inundation are clustered in the upper left of the figure. Similar patterns arise in correlating species with these environmental variables (Axis 1, Figure 2.34.). Species growing in drier soils are arrayed to the right, and species adapted to inundation and saturated soils toward the left and upper left of the figure. Seasonal declines in reservoir water levels combined with extensive sediment deposits have resulted in a unique array of species in this reach (Table 2.2., Appendix 2.1).

Composition of Shoreline Plant Communities

Species composition of the mudflat communities on the Powder River Arm was unique relative to the other study reaches. A number of different assemblages were associated with the following shoreline vegetation zones/habitat types: 1) barren zone ($<$ full pool), 2) obligate riparian zone (\leq full pool), 3) facultative/transitional zone (\geq full pool), and 4) upland zone ($>$ full pool) (Table 2.11., Figure 2.35.).

Annual bluegrass (*Poa annua*), Common cocklebur (*Xanthium strumarium*) and Purslane/Tumble Pigweed (*Portulaca oleracea/Amaranthus alba*), Water smartweed (*Polygonum amphibium*), and witchgrass (*Panicum capillare*) were common assemblages in barren mudflats (Table 2.11.). Some species commonly associated with these assemblages included: *Amaranthus retroflexus*, *Echinochola crus-galli*, *Euphorbia glyptosperma*, and *Rumex crispus* (Table 2.2., Appendix 2.1). On these exposed mudflats, annual-dominated assemblages were noted for high levels of plant cover (10% to 50%, Figure 2.13c.) relative to barren habitats in other reaches (< 5% to 10%, Figures 2.13. and 2.22.).

Coyote willow (*Salix exigua*) and reed canarygrass (*Phalaris arundinacea*) were the most common assemblages found in obligate riparian zones (Table 2.11.). These assemblages were widely distributed, and in some cases limited to isolated patches of 1–2 individuals or clonal clumps at the full pool elevation. When present, coverage values were high, ranging from 30 to 50⁺% (Figure 2.13c.).

Coyote willow (*Salix exigua*) was the most common assemblage in the facultative and transitional zone for this reach (Table 2.11.). Coverage values were high (30 to 60%, Figure 2.13c.), with associated species including *Agropyron repens*, *Bromus tectorum*, *B. japonicus*, *Cirsium arvense*, *Conyza Canadensis*, and *Taeniatherum caput-medusae* (Table 2.2., Appendix 2.1).

Upland plant assemblages were largely composed of mixed grass/forb assemblages (Table 2.11.). A diverse number of annual and perennial grasses and forbs were associated with this assemblage (Table 2.2. and Appendix 2.1 list the common forbs and grasses in this reach.).

2.3.3.3. Hells Canyon Reservoir - Oxbow Bypass (OB; River Mile 272.7 to 270.1)

The Oxbow Bypass is exposed to fluctuating backwater impoundments, periodic spillway releases, and storm-related overflows. As a result, shorelines were heavily armored, yet fine substrates were still relatively common (Figure 2.23.).

Grasses and Forbs

Grasses and forbs were the most common life forms in the Oxbow Bypass reach, with forbs being more abundant than grasses (Figures 2.36., 2.21a.). Annual grasses (i.e., *Bromus japonicus*, *Echinochola crus-galli*, *Panicum capillare* and *Taeniatherum caput-medusae*) were more common than perennial grasses (*Poa pratensis* and *Sporobolus cryptandrus*) (Table 2.2., Appendix 2.1). In contrast, the relative abundance of perennial forbs (*Artemisia ludoviciana*, *Lepidium latifolium*, *Grindelia squarrosa*, etc.) was similar to that of annual forbs (*Amaranthus albus*, *Euphorbia glyptosperma*, and *Xanthium strumarium*, Figures 2.36., 2.21a., 2.22a., Table 2.2., Appendix 2.1). Diurnal surface water fluctuations (+/- 1 to 2 m) combined with the absence of pronounced seasonal declines in water levels contribute to high levels of grass and forb cover near full pool (20–25%, Figures 2.21a., 2.22a.). Soil and substrate affinities ranged from fine to coarse substrates (n = 15 to 83, Figure 2.23.). Repeated disturbance by diurnal inundation appears to be an important factor regulating the abundance of annual and perennial forbs in this reach.

Trees and Shrubs

Similar to the shorelines of adjacent reservoirs, woody plants were a highly visible component of the Oxbow Bypass flora (Figures 2.36., 2.22a.). Common woody species included: false indigo (*Amorpha fruticosa*), netleaf hackberry (*Celtis reticulata*), poison ivy (*Toxicodendron radicans*), and sandbar willow (*Salix exigua*) (Table 2.2., Appendix 2.1.). The relative diversity of species was lower than along adjacent reservoir reaches, with woody vegetation limited to facultative or obligate riparian habitats near full pool (Figures 2.36., 2.21a., 2.22a.). Relative cover (Figure 2.21a.) was similar for forbs, grasses, shrubs and trees, yet average cover per quadrat (Figure 2.22a.) was significantly higher for woody species. The substrate affinities of woody species were similar to grasses and forbs, ranging from fine soils to coarse cobbles (Figure 2.23.).

Correlations with Environmental Variables

Plant distribution was strongly correlated with hydrologic variables, and weakly correlated with slope and substrate properties. Distribution patterns were strongly correlated with 1) full pool elevation, 2) days inundated per year, 3) last day of the year inundation occurred, and 4) the maximum duration of dry conditions ($r = 0.695$ to 0.939 , Table 2.12.). There was a high species: environment correlation ($r = 0.976$) for this data set, yet the percent of the variance explained by each axis was low (5.5 to 7.5%, Table 2.12.).

A CCA ordination of sample quadrats and species is shown in Figures 2.37. and 2.38. Upland quadrats are arrayed to the left and frequently inundated quadrats toward the right side of the diagram (Axis 1, Figure 2.37.). Those areas subject to frequent inundation are clustered in the upper right, with upland habitats arrayed to the left side of the figure. Similar patterns arise in the correlating species distributions with these environmental variables (Figure 2.38.). Species growing in drier soils are arrayed to the left, and species adapted to inundation and saturated soils toward the upper right of the figure (Axis 1). A strong correlation with full pool conditions ($r = 0.938$) is shown by the similar orientation and the length of the full pool axis relative to Axis 1 (Figures 2.37. and 2.38.). This suggests that repeated inundation of shorelines was a significant factor influencing plant distribution in this reach.

Composition of Shoreline Plant Communities

Plant assemblages in the Oxbow bypass were somewhat intermediate in character to the shoreline communities of Brownlee, Oxbow and Hells Canyon Reservoirs. Approximately two assemblages were associated with the following shoreline vegetation zones/habitat types: 1) barren zone ($<$ full pool), 2) obligate riparian zone (\leq full pool), 3) facultative/transitional zone (\geq full pool), and 4) upland zone ($>$ full pool) (Table 2.13., Figure 2.27.).

Common cocklebur (*Xanthium strumarium*) and Purslane/Tumble Pigweed (*Portulaca oleracea/Amaranthus alba*) were the most common assemblages found in barren draw-down zones (Table 2.13.). Some species commonly associated with these assemblages included: *Digitaria sanguinalis*, *Echinochola crus-galli*, *Euphorbia glyptosperma*, *Panicum capillare* and *Poa annua* (Table 2.2., Appendix 2.1). These assemblages were noted for their low cover (7% to 22%) relative to other shoreline habitats (25% to 85%, Figure 2.22a.).

False indigo (*Amorpha fruticosa*) and coyote willow (*Salix exigua*) were common assemblages in obligate riparian zones (Table 2.13.). These assemblages were highly fragmented in their distribution, but when present coverage values were high, ranging from 25 to 55+% (Figure 2.22a.). Species commonly associated with these assemblages, included *Artemisia ludoviciana*, *Asclepias speciosa*, *B. japonicus* and *Taeniatherum caput-medusae* (Table 2.2., Appendix 2.1).

False indigo (*Amorpha fruticosa*) and netleaf hackberry (*Celtis reticulata*) were common assemblages in the facultative and transitional zones (Table 2.13.). Cover values for these woody-dominated assemblages were relatively high (25 to 80%, Figure 2.22a.). Associated species included annual and perennial grasses (i.e., *Bromus japonicus*, *Poa pratensis* and *Sporobolus cryptandrus*, *Taeniatherum caput-medusae*) and annual and perennial forbs, i.e., (*Artemisia ludoviciana*, *Asclepias speciosa*, *Conyza canadensis*, *Helianthus annuus*, *Lactuca serriola*, *Lepidium latifolium*, *Melilotus officinalis* and *Toxicodendron radicans*) (Table 2.2., Appendix 2.1).

Upland plant assemblages were largely composed of mixed grass/forb assemblages (Table 2.13.). A diverse number of annual and perennial grasses and forbs were commonly associated with these assemblages (Table 2.2. and Appendix 2.1).

2.3.4. Annual and Seasonal Hydrology of Riverine Reaches

2.3.4.1. Weiser Reach of the Snake River (WR; River Mile 351.2 to 342.9)

Historic patterns of annual discharge (maximum, minimum, and mean) provide important indicators of the boundary flow conditions for the Weiser Reach of the Snake River (Figure 2.2.). Throughout the period of record (1911 to 1999), maximum peak flows varied significantly in response to changing snowpack and climatic conditions. Annual maxima ranged from lows between 18000 and 22000 cfs to highs between 75000 and 84000 cfs (Figure 2.2.). Mean annual discharge has also varied significantly, with the lowest annual flows (8800 to 10500 cfs) recorded during the drought of 1987 to 1992 and some of the highest annual flows (over 30000 cfs) between 1982 and 1986. Minimum annual discharge has been relatively consistent from year to year; ranging from 5000 to 11000 cfs.

Seasonal patterns of discharge or mean daily flow (i.e., seasonal hydrographs) indicate important environmental cues for the establishment and growth of riparian vegetation. The cumulative effects of water development within a river basin are also revealed through the comparative analysis of seasonal discharge patterns from one decade to the next (Figure 2.3.). Seasonal flow patterns prior to significant water development within the Snake Basin (1911–1921) showed high levels of runoff during springtime snowmelt, where the volume of peak runoff was more than five times higher than summer baseflow conditions (Figure 2.3.). As water development within the basin progressed over time, this ratio of peak runoff to baseflow discharge progressively declined to 2.8 in the decade before construction of Brownlee Dam (1948–1958) and 2.5 in the most recent decade (1990–1999) (Figures 2.3., 2.4.).

Similar to the modifications of low flows, the timing and duration of peak flows have been shifted from a single springtime peak flow event (1911–1921) to a more bimodal pattern of early

season discharge (Figures 2.3., 2.4.). In effect, the water development projects have diminished springtime peak flows and elevated summer baseflows. These shifts in seasonal discharge not only alter fluvial geomorphic processes, such as sediment transport and deposition, they also significantly alter the environmental conditions for plant growth within these riparian corridors. As the life history and ecology of riparian plants is commonly linked to seasonal flow patterns, these cumulative changes in seasonal discharge are critical to our understanding of factors governing the composition of riparian plant communities. It is also important to note that seasonal flow regimes had been significantly altered prior to the completion of Brownlee Dam.

A detailed assessment of seasonal flow regimes in the decades following the completion of Hells Canyon Dam (Figure 2.39.) provides an opportunity to directly compare inflows to water-level fluctuations within Brownlee, Oxbow and Hells Canyon Reservoirs. It also permits the assessment of subsequent flow releases to the Hells Canyon Reach of the Snake River (Figure 2.40.).

2.3.4.2. Hells Canyon Reach of the Snake River (SN; River Mile 247.7 to 188.2)

As the Hells Canyon Complex of reservoirs holds only about 10% of the mean annual volume of the Snake River, they provide relatively limited impacts on downstream flows (Figure 2.39.). There is a slight attenuation of short-term patterns such as instantaneous peak flows. However, with daily averaging, these impacts are slight and consequently, downstream maximum, average and minimal daily flows below Hells Canyon Dam closely matched the inflows from the Weiser Reach during the post-damming period (Figure 2.39.).

Consistent with the similarity of annual hydrograph statistics (Figure 2.39.) seasonal flow patterns are also minimally altered by the Hells Canyon Complex. Consequently, seasonal flows below Hells Canyon Dam have closely followed the inflows from the Weiser reach (Figure 2.40.). There was some smoothing of the hydrographs, in addition to some flow capture during the rising limb of the hydrograph (Figure 2.40.). Thus, downstream flows were slightly reduced from February through April and thereafter sometimes slightly elevated in June through September. In the 1990's, there was also a later season pattern in which elevated downstream flows would be released in September and early October; reducing downstream flows from mid-October through November (Figure 2.40.). Altered flow patterns during the spring and summer would have greater impacts on riparian vegetation whereas altered flows in October and November would have less impact since most riparian plants would be dormant.

2.3.5. Plant Distribution Patterns along Unimpounded Reaches

2.3.5.1. Weiser Reach of the Snake River (WR; River Mile 351.2 to 342.9)

The regulated flow regime of the Weiser Reach has significantly altered the environmental conditions for plant growth within this riparian corridor (Figures 2.2., 2.3. and 2.40.). In conjunction with cumulative effects arising from changes in annual and seasonal discharge patterns, the composition of riparian plant communities has largely shifted from native species to exotic and invasive plants (2001).

Grasses and Forbs

Grasses and forbs (including many exotic, invasive and noxious species) were widespread throughout this reach (Figure 2.41.). Typically, annual grasses (i.e. *Heleochloa alopecuroides*, *Echinochola crus-galli*, and *Panicum capillare*) were more common than perennial grasses (*Elymus cinereous* and *Phalaris arundinacea*) (Figure 2.41., Table 2.2., Appendix 2.1). In contrast, the relative abundance of perennial forbs (*Convolvulus arvensis*, *Lepidium latifolium*, *Plantago major*, etc.) was similar to annual forbs (*Amaranthus albus*, *Conyza canadensis*, *Euphorbia glyptosperma* and *Xanthium strumarium*, Figure 2.41., Table 2.2., Appendix 2.1). The relative abundance and cover of grasses and forbs were significantly higher at riverbank elevations ranging from the mean annual water level (MAWL) up to 2 meters above MAWL throughout this reach (Figures 2.41. to 2.44.). The substrate affinities of grasses and forbs ranged from fine soils to coarser gravels with interstitial fines (Figures 2.44., 2.45.).

Trees and Shrubs

Riparian tree and shrub species were a highly visible component of the flora along the Weiser Reach. Many of these species are considered exotic along western riparian corridors (Table 2.2., Appendix 2.1). Common tree species included silver maple (*Acer saccharinum*), American and Chinese elm (*Ulmus americana* and *U. parvifolia*), Russian olive (*Eleagnus angustifolia*) and white alder (*Alnus rhombifolia*). Some common shrub species included false indigo (*Amorpha fruticosa*), wood rose (*Rosa woodsii*), peachleaf willow (*Salix amygdaloides*), sandbar willow (*Salix exigua*) and salt cedar (*Tamarix complex*) (Table 2.2., Appendix 2.1). Trees and shrubs in this reach ranged from approximately 10 years old for salt cedar, up to 40–43 years for elms and silver maple (Table 2.14.). The relative diversity of woody species was greater than in adjacent reservoir reaches, although riparian woody plants generally grew in a very narrow band (5–15 m wide) at approximately 1 to 2 meters above the mean annual water surface elevation (Figures 2.41. to 2.43.). Relative percentage of cover (Figure 2.43.) was similar for forbs, grasses, shrubs and trees, yet average cover per quadrat (Figure 2.42.) was greater for woody species. The substrate affinities of woody species were similar to grasses and forbs, ranging from fine silts and sandy soils to coarse cobbles with interstitial fines (Figures 2.44., 2.45.).

Correlations with Environmental Variables

Riparian plant assemblages along the Weiser Reach were spatially confined to a relatively narrow zone that was approximately 5 to 15 m wide and 1 to 2 m above the mean annual water surface.

Plant distribution was strongly correlated with hydrologic variables, and weakly correlated with slope and substrate properties. Distribution patterns were most strongly correlated with 1) mean annual water levels, 2) summer baseflow conditions, and 3) average peakflow ($r = 0.737$ to 0.796 ; Table 2.15.). Substrate conditions were a more significant environmental variable than riverbank slope (Table 2.15.). There was a high species versus environment correlation ($r = 0.924$) for this data set, yet the cumulative variance explained by each axis was relatively low (4.1 to 8.8%, Table 2.15.).

A CCA ordination of sample quadrats and species is shown in Figures 2.46. and 2.47. Upland quadrats are arrayed to the left and frequently inundated quadrats toward the right side of the

diagram (Axis 1, Figure 2.46.). Similar patterns arise in the correlating species distributions with these environmental variables (Figure 2.47.). Species growing in drier soils are arrayed to the left, and species adapted to inundation and saturated soils toward the lower right of the figures (Axis 1). Strong correlations with hydrologic conditions ($r = 0.796$; Table 2.15.) were shown by their relative axis orientation and length along Axis 1 (Figures 2.46. and 2.47.). However, there were important interactions between these hydrologic variables, slope and substrate conditions along this reach.

2.3.5.2. Hells Canyon Reach of the Snake River (SN; River Mile 247.7 to 188.2)

The regulated flow regime below Hells Canyon Dam (Figures 2.39., 2.40.) appears to have had only moderate effects on the composition and structure of riparian plant communities along this reach. These moderate effects appear largely related to the general lack of major stage fluctuations at elevations corresponding to the narrow and fragmented bands of riparian vegetation growing along the canyon corridor. In effect, most of the regulated stage fluctuations occur along lower rocky and barren riverbanks approximately 2 to 3 m below riparian plant communities.

Grasses and Forbs

Grasses and forbs (including several exotic species) were widespread throughout this reach (Figure 2.48.). Annual grasses (*Panicum capillare*, *Cenchrus longispinus*) were more common than perennial grasses (Figure 2.48.). In contrast, the relative abundance of perennial forbs (*Physalis longifolia*, *Artemisia ludoviciana*, *A. lindleyana*, *Glycyrrhiza lepidota*) was significantly greater than annual species (*Euphorbia glyptosperma*) (Figure 2.48.). The relative abundance and cover of grasses and forbs were higher at riverbank elevations ranging from the mean annual water level (MAWL) up to 4 m above MAWL throughout this reach (Figure 2.48.). The substrate affinities of grasses and forbs ranged from fine soils to coarser cobbles with interstitial fines (Figures 2.44., 2.45.).

Trees and Shrubs

Riparian woody plants, notably netleaf hackberry (*Celtis reticulata*), were a highly visible component of the Hells Canyon Reach of the Snake River (Figure 2.48.). The distribution of hackberry ranged from small, isolated stands to large, extensive stands along the river channel. In many areas, root suckers of hackberry were commonly observed within rocky, barren substrates at lower riverbank elevations. Additional woody species that contributed to vertical vegetation structure included coyote willow (*Salix exigua*) and less commonly, white alder (*Alnus rhombifolia*).

Correlatins with Environmental Variables

Plant distribution was strongly correlated with hydrologic variables, and weakly correlated with slope and substrate properties. Distribution patterns were most strongly correlated with 1) mean annual water levels, 2) summer baseflow conditions, and 3) max and mean peak flows ($r = 0.646$ to 0.786 ; Table 2.16.). Similar to other reaches, substrate conditions were a more significant environmental variable than riverbank slope (Table 2.16.). There was a moderate species versus

environment correlation ($r = 0.811$) for this data set, and the cumulative variance explained by each axis was relatively low (1.8 to 3.2 %, Table 2.16.).

A CCA ordination of sample quadrats and species is shown in Figures 2.49. and 2.50. Upland quadrats are arrayed to the right and frequently inundated quadrats toward the left side of the diagram (Axis 1, Figure 2.49.). Similar patterns arise in the correlating species distributions with these environmental variables (Figure 2.50.). Species growing in drier soils are arrayed to the right, and species adapted to scouring and inundation toward the left of the figure (Axis 1). Correlations with hydrologic conditions ($r = 0.786$; Table 2.16.) were shown by their relative axis orientation and length along Axis 1 (Figures 2.49. and 2.50.). There are also important interactions between these hydrologic variables and substrate conditions along this reach.

2.3.6. Longitudinal Patterns in Plant Distribution

An initial analysis of the longitudinal distribution of riparian plants is shown in Figure 2.51. This graphic designates plants in three comparative groupings. The top group contrasts native versus exotic species and further indicates those exotic species that are designated as noxious (Krichbaum 2000). As indicated, except in one entirely barren transect along Brownlee Reservoir, native species occurred along all transects. Exotic plants also occurred along all transects except a few along the Hells Canyon reservoir and Hells Canyon reach of the Snake River.

The second group compares longitudinal occurrence based on life history duration. Annuals were widespread but a number of transects along Brownlee Reservoir reach lacked perennials (Figure 2.51.). Woody plants were common along most reaches except for the Brownlee Reservoir reach. This distribution would be consistent with the progressive expansion of woody plants in the downstream direction from the source populations of the upstream river and transitional reaches along with tributary drainages. Seedlings of woody plants were sparse along the corridor except along the Weiser and Hells Canyon reaches of the Snake River (Figure 2.51.).

The third group assigns local species to the vegetation groups that are modeled in Chapter 3. As indicated, hydrophytes were sparse along Brownlee and Hells Canyon Reservoirs, including the Oxbow Bypass reach but were more common along the Oxbow Reservoir (Figure 2.51.). Such differences between the Oxbow and Hells Canyon reservoirs were somewhat unexpected.

Ruderal annuals are weedy annuals that are effective at colonizing the draw-down zones along Brownlee Reservoir. Plants of this vegetation group were abundant along the corridor downstream through the Brownlee Reservoir but were subsequently less common along the Oxbow Reservoir and absent from many transects along the downstream portion of the Hells Canyon Reservoir (Figure 2.51.). This is potentially a very important pattern relative to the dispersal of exotic ruderal annuals, including some noxious weeds, since their deficiency along the final reservoir reach should reduce their downstream dispersal to the Hells Canyon reach of the Snake River.

This longitudinal comparison can be expanded by analyzing the elevational position and proportional occurrence of the vegetation groups across the eight study reaches. This comparison extends from the Weiser reach of the Snake River upstream of Brownlee Reservoir, through the

three study reaches of Brownlee Reservoir, the three study lower reservoir study reaches and finally, to the Snake River below Hells Canyon Dam (Figure 2.52.).

In this figure, the Weiser Reach is only partially represented (Figure 2.52.) since above the band of fairly dense woody riparian vegetation, other artificial impacts occur such as those associated with agricultural production. Among the other reaches three patterns emerge relative to typical elevational distribution of riparian plants. For the three study reaches along Brownlee Reservoir, the zone of woody riparian vegetation occurs near the full pool elevation (Figure 2.52.). In contrast, herbaceous plants extend downwards to as far as 10 m below full pool. The second pattern occurs downstream, along the lower reservoirs (Figure 2.52.). Here, both woody and herbaceous riparian plants co-occur in a relatively narrow elevational band above full pool. Finally, along the lowest study reach, the Snake River reach through Hells Canyon, both woody and herbaceous plants occur over a relatively broad band above the mean annual water level (Figure 2.52.).

As shown in Figure 2.53., both the native and exotic herbaceous (non-woody) plants were generally widespread across the elevational profiles and study reaches. Some proportional differences occurred across the reaches such as the prominence of exotic herbaceous plants along the Brownlee Reservoir reaches. This was particularly the case for the Powder River Arm.

Proceeding downstream, similar proportions of native and exotic riparian plants occurred in quadrats along the lower reservoir reaches (Figure 2.53.). There is also an indication of a progressive trend whereby the lowest reservoir reaches and, especially the Hells Canyon Reservoir, has a higher proportion of native herbaceous plants in the zone above full pool. The trend continues downstream to the Snake River reach below Hells Canyon Dam. Thus, in the zone above the mean annual water level, native plants dominate this flow-regulated riverine reach (Figure 2.53.).

The longitudinal pattern in native versus exotic plants is even more pronounced among the woody species (Figure 2.54.). Progressing along the Snake River corridor there are substantial differences in the proportions of native versus exotic woody plants. The Weiser Reach of the Snake River is dominated by exotic species including some potentially invasive trees, notably Russian olive (*Eleagnus angustifolia*) and tamarisk (*Tamarix* complex).

The Brownlee Reservoir Headwater reach is dominated by exotic woody plants (Figure 2.54.), with tamarisk being the most common woody exotic. In contrast, the Powder River Arm, the second transitional lotic-lentic reach, principally supported native sandbar and Pacific willows. (For these analyses, it should be recognized that the present study applied a stratified-random sampling strategy, not a comprehensive inventory, but quantitative patterns are generally consistent with Holmstead (2001) and Krichbaum (2000).

Along the main Brownlee Reservoir, the exotic tree, false indigo, and the native shrub, sandbar willow, were the most common woody plants along the transects. Hackberry was also common and combined with the sandbar willow to provide a dominance of native woody plants along this reach (Figure 2.54.).

The three lower reservoir reaches had relatively similar proportions of native and exotic woody plant quadrats, although there were some differences across the three reaches (Figure 2.54.). There was little evidence of a progressive downstream trend along these reaches, with considerable numbers of false indigo along with a few other exotic trees. Prominent native woody plants included hackberry and sandbar willow.

Finally and most notably, the river riparian zone of the Snake River below Hells Canyon was dominated by native woody plants (Figure 2.54.). Exotic trees were noted but generally occurred on (upland) terraces near settlements. No exotic trees or shrubs were noted along the riparian transects sampled. However, Holmstead (2001) and Krichbaum (2000) reported that false indigo occasionally occurs along the reach. Thus, the data presented in the lowest plot of Figure 2.54. reflect a scarcity but not a total absence of exotic woody plants within the active riparian zones along the Hells Canyon Reach of the Snake River.

Table 2.1. Abbreviations for the canonical correspondence analysis (CCA) environmental variables as described in Section 2.2.2.2 of the text.

| Abbreviation of Variable | Description of Variable |
|--------------------------|--|
| | <i>(Elevation relative to:)</i> |
| EBF/EMINBF | baseflow |
| EAVEP | average peakflow |
| EMAWL/EfromMAW | mean annual water level |
| EMAXP/EMAXPF | max peakflow |
| EfromMea | mean baseflow |
| EfromMin | min baseflow |
| EfromMea | mean peakflow |
| EfromMax | max peakflow |
| FP | full pool |
| MAWL | mean annual water level |
| MHWM | mean high water mark |
| MLWM | mean low water mark |
| MAXDURFL/MAXFLD | max duration of flooding |
| MAXDURDR/XDRY/MAXDRY | max duration of dry period |
| DAYSFLD | days flooded per year |
| FIRSTDAY | first day of flooding per year |
| LASTDATE/LASTDAY | last day of flooding per year |
| NUMFLD | number of days flooded per year |
| TIMESFLD | number of different times flooded per year |
| SLOPE | overall slope of transect |

Table 2.2. The prevalence (% of quadrats where present per reach) of the 10 most common species in each life-form along the Weiser Reach (WR), Brownlee Reservoir - Headwater (BH), - Main (BM), - Powder River Arm (BP), Oxbow Reservoir - Main (OM), Hells Canyon Reservoir - Oxbow Bypass (OB), - Main (HM), and Snake River Reach (SN).

| Life-form | Code | Species | WR | BH | BM | BP | OM | OB | HM | SN |
|-------------------|------|-----------------------------------|------|------|------|------|------|------|------|------|
| Annual Grasses | BRJA | <i>Bromus japonicus</i> | | | 2.7 | 2.1 | 21.6 | 5.4 | 15.8 | |
| | BRST | <i>Bromus sterilis</i> | | | 0.9 | | 5.9 | | 8.3 | 6.3 |
| | BRTE | <i>Bromus tectorum</i> | 1.6 | 5.8 | 10.4 | 1.0 | 32.4 | 1.8 | 35.3 | 11.9 |
| | DISA | <i>Digitaria sanguinalis</i> | 4.7 | 0.7 | 0.1 | | | | | |
| | ECCR | <i>Echinochola crus-galli</i> | 8.6 | 12.7 | 2.5 | 15.6 | | 3.6 | | 0.1 |
| | FEOC | <i>Festuca octoflora</i> | | 0.3 | | | | | 3.0 | |
| | HEAL | <i>Heleochloa alopecuroides</i> | 28.9 | 13.1 | | | | | | |
| | PACA | <i>Panicum capillare</i> | 10.9 | 11.3 | | 16.1 | | 3.6 | | 10.8 |
| | POAN | <i>Poa annua</i> | | 10.0 | 1.4 | 49.5 | | 1.8 | | |
| | TACA | <i>Taeniatherum caput-medusae</i> | 0.8 | | 3.5 | 1.0 | 22.5 | 5.4 | 6.0 | 0.1 |
| Annual Forbs | AMAL | <i>Amaranthus albus</i> | 5.5 | 22.0 | 19.0 | 10.9 | 2.9 | 3.6 | 1.5 | 0.5 |
| | COCA | <i>Conyza canadensis</i> | 20.3 | 2.4 | 0.3 | 2.1 | 2.0 | 3.6 | | 1.1 |
| | EPPA | <i>Epilobium paniculatum</i> | 0.8 | 1.4 | 1.1 | | 7.8 | | 6.8 | 0.1 |
| | EUGL | <i>Euphorbia glyptosperma</i> | 11.7 | 0.7 | 1.2 | 2.6 | | 19.6 | | 9.0 |
| | HEAN | <i>Helianthus annuus</i> | 0.8 | 0.7 | 1.8 | | 6.9 | 1.8 | 1.5 | 2.5 |
| | LASE | <i>Lactuca serriola</i> | 10.2 | 1.0 | 2.2 | 2.6 | 13.7 | | 5.3 | 1.2 |
| | MEOF | <i>Meliolotus officinalis</i> | | 1.4 | 2.7 | 0.5 | 9.8 | 1.8 | 4.5 | 10.8 |
| | POAV | <i>Polygonum aviculare</i> | 3.1 | 0.7 | 0.2 | 1.6 | 2.9 | | 0.8 | |
| | POOL | <i>Portulaca oleracea</i> | 10.2 | 34.7 | 21.1 | 60.4 | | 3.6 | | 0.6 |
| | XAST | <i>Xanthium strumarium</i> | 19.5 | 61.5 | 21.4 | 22.4 | | 25.0 | 0.8 | 4.0 |
| Perennial Grasses | AGRE | <i>Agropyron repens</i> | | | | 1.0 | | | | |
| | AGSP | <i>Agropyron spicatum</i> | | | 0.8 | | 3.9 | | 25.6 | 9.0 |
| | DAGL | <i>Dactylis glomerata</i> | | | | | | | 1.5 | |
| | ELCI | <i>Elymus cinereus</i> | 7.8 | 0.3 | | | | | | |
| | PHAR | <i>Phalaris arundinacea</i> | 19.5 | 2.7 | 0.2 | 5.7 | | | 3.0 | 0.1 |
| | POBU | <i>Poa bulbosa</i> | | | 0.2 | | | | 0.8 | |
| | POPR | <i>Poa pratensis</i> | | | 0.9 | | 6.9 | 3.6 | 8.3 | |
| | POSE | <i>Poa secunda</i> | | 0.3 | 1.4 | | 2.0 | | 6.8 | |
| | SPCR | <i>Sporobolus cryptandrus</i> | | | 0.4 | | | 7.1 | 2.3 | |
| | STOC | <i>Stipa occidentalis</i> | | | | | | | 1.5 | 0.7 |
| Perennial Forbs | ARLU | <i>Artemesia ludoviciana</i> | | 0.3 | | | 10.8 | 19.6 | 1.5 | 8.9 |
| | ASSP | <i>Asclepias speciosa</i> | 3.9 | | 0.7 | 0.5 | 5.9 | 1.8 | 3.0 | 1.0 |
| | COAR | <i>Convolvulus arvensis</i> | 10.9 | 1.4 | 2.8 | | 3.9 | | 3.0 | 1.2 |
| | DISY | <i>Dipsacus sylvestris</i> | | | 0.1 | 2.1 | 17.6 | 1.8 | 8.3 | 1.1 |
| | GRSQ | <i>Grindelia squarrosa</i> | | 0.7 | 0.6 | | 4.9 | 3.6 | 1.5 | 2.5 |
| | IRPS | <i>Iris pseudoacorus</i> | 2.3 | 0.3 | | | 15.7 | | 0.8 | |

Table 2.2. (Cont.)

| Life-form | Code | Species | WR | BH | BM | BP | OM | OB | HM | SN |
|---|------------------------|-------------------------------|------|------|-----|-----|------|-----|------|------|
| Perennial Forbs (cont.) | LELA | <i>Lepidium latifolium</i> | 25.8 | 6.5 | 2.1 | | 18.6 | 7.1 | 6.0 | |
| | PLMA | <i>Plantago major</i> | 10.2 | 0.3 | | 0.5 | 1.0 | 3.6 | | |
| | RUCR | <i>Rumex crispus</i> | 0.8 | 0.3 | 0.1 | 1.0 | 2.0 | | 0.8 | 0.2 |
| | VETH | <i>Verbascum thapsus</i> | 0.8 | | 0.8 | | 2.0 | | 12.0 | 2.2 |
| Woody Species | AMAL2 | <i>Amelanchier alnifolia</i> | | | 0.2 | | 2.9 | | 2.3 | 0.6 |
| | AMFR | <i>Amorpha fruticosa</i> | 5.5 | 4.5 | 3.0 | | 17.6 | 5.4 | 13.5 | |
| | ARTR | <i>Artemesia tridentata</i> | | 1.0 | 3.2 | | 5.9 | | 0.8 | 0.1 |
| | CERE | <i>Celtis reticulata</i> | | | 1.2 | | 13.7 | 5.4 | 17.3 | 18.0 |
| | ELAN | <i>Elaeagnus angustifolia</i> | 5.5 | 0.3 | 0.1 | | 2.9 | | | |
| | ROWO | <i>Rosa woodsii</i> | 14.8 | | 0.3 | | 7.8 | | 5.3 | 0.2 |
| | SAEX | <i>Salix exigua</i> | 14.8 | 12.0 | 2.8 | 7.8 | 14.7 | 7.1 | | 3.3 |
| | SALA | <i>Salix lasiandra</i> | 2.3 | 7.9 | | 2.1 | | | | |
| | TARA | <i>Tamarix ramosissima</i> | 8.6 | 14.8 | | | | | | |
| | TORA | <i>Toxicodendron radicans</i> | | | 0.2 | | 12.7 | 3.6 | 9.8 | 3.7 |
| ULAM | <i>Ulmus americana</i> | 1.6 | | | | 1.0 | | 4.5 | | |
| Number of quadrats surveyed in each reach = | | | 128 | 291 | 905 | 192 | 102 | 56 | 133 | 177 |
| | | | | | | | | | | 1 |

Table 2.3. Summary of canonical correspondence analysis (CCA) statistics for Brownlee Reservoir–Main (BM)

```

-----
Part A:  AXIS SUMMARY STATISTICS - Number of canonical axes: 3
Total variance ("inertia") in the species data: 21.8701
          Axis 1   Axis 2   Axis 3
Eigenvalue      0.884    0.423    0.317
Variance in species data
  % of variance explained      4.0     1.9     1.5
  Cumulative % explained      4.0     6.0     7.4
Pearson Correlation, Spp-Envt*  0.955    0.757    0.683
Kendall (Rank) Corr., Spp-Envt  0.502    0.399    0.368
-----

Part B:  INTER-SET CORRELATIONS for 9 Environmental Variables
          Correlations
Variable   Axis 1   Axis 2   Axis 3
1 SUBSTR      0.285  -0.306  0.396
2 SLOPE      -0.232  0.469  0.318
3 FP         -0.872  -0.002  0.123
4 DAYSFLD     0.938   0.059  0.001
5 FIRSTDAY   -0.099  -0.291  0.107
6 LASTDAY     0.856  -0.145  0.173
7 NUMFLD     0.538  -0.251  0.166
8 MAXFLD     0.943   0.056  0.024
9 MAXDRY    -0.874   0.122 -0.150

```

Table 2.4. Common plant assemblages, vegetation zones and cover types for the shorelines of Brownlee Reservoir–Main (BM).

| Vegetation Zone | Plant Assemblage ¹ | Cover Type ² |
|--------------------------|-------------------------------|-------------------------|
| Barren | Common cocklebur | SBW |
| | Purslane/Tumble pigweed | SBW |
| Obligate Riparian | False Indigo | SSW |
| | Reed canarygrass | EHW |
| Facultative/Transitional | False Indigo | SSW |
| | Netleaf hackberry | SSW |
| Upland | Big sagebrush | SS |
| | Mixed grass/forb | G |

¹ See text for description of plant assemblages.

² IPC Cover type codes: EHW = *Emergent Herbaceous Wetland*, SBW = *Shore and Bottomland Wetland*, SSW = *Scrub-Shrub Wetland*, SS = *Shrub Savannah*, G = *Grassland*. See technical report E.3.3-1 for a description of these cover types.

Table 2.5. Estimated ages for select trees along Oxbow Reservoir–Main (OM), Hells Canyon Reservoir–Main (HM), and Brownlee Reservoir–Headwater (BH). Ages were based on ring-counts of tree cores collected along the transects.

| Common Name | Species | Sample size (n) | Mean Age ± SD |
|-------------------|------------------------------|-----------------|---------------|
| European willow | <i>Salix alba</i> | 2 | 15 ± 0.7 |
| Netleaf hackberry | <i>Celtis reticulata</i> | 3 | 43 ± 31.5 |
| Russian olive | <i>Eleagnus angustifolia</i> | 2 | 20 ± 0.7 |
| Salt cedar | <i>Tamarix complex</i> | 2 | 9 ± 0.9 |
| Siberian elm | <i>Ulmus pumila</i> | 2 | 18 ± 0.7 |

Table 2.6. Summary of canonical correspondence analysis (CCA) statistics for Main Oxbow and Hells Canyon reservoirs (OM, HM).

```

-----
Part A:  AXIS SUMMARY STATISTICS - Number of canonical axes: 3
Total variance ("inertia") in the species data: 23.4269
          Axis 1   Axis 2   Axis 3
Eigenvalue      0.534    0.431    0.299
Variance in species data
  % of variance explained      2.3     1.8     1.3
  Cumulative % explained      2.3     4.1     5.4
Pearson Correlation, Spp-Envt*  0.840    0.775    0.715
Kendall (Rank) Corr., Spp-Envt  0.587    0.591    0.466
-----

Part B:  INTER-SET CORRELATIONS for 9 Environmental variables
          Correlations
Variable   Axis 1   Axis 2   Axis 3
1 SUBSTR   0.161  -0.175   0.638
2 SLOPE    0.624   0.465   0.124
3 FP       0.617  -0.278  -0.233
4 DAYSFLD -0.469   0.191   0.202
5 FIRSTDAY -0.397   0.400   0.234
6 LASTDAY  -0.453   0.340   0.332
7 TIMESFLD -0.494   0.243   0.255
8 MAXFLD   -0.399   0.139   0.197
9 MAXDRY   0.495  -0.319  -0.304
-----

```

Table 2.7. Common plant assemblages, vegetation zones and cover types for the shorelines of Oxbow Reservoir–Main (OM) and Hells Canyon Reservoir – Main (HM).

| Vegetation Zone | Plant Assemblage* | Cover Type** |
|----------------------|--------------------------|-------------------------|
| Barren | Absent | SBW |
| Obligate Riparian | Coyote willow | SBW/SSW |
| | False indigo | SSW |
| | Reed canarygrass | EHW |
| | Smooth scouring rush | EHW |
| | Yellow flag | EHW |
| | Facultative/Transitional | Broad-leaved pepperweed |
| False indigo | | SSW |
| Himalayan blackberry | | SSW |
| Netleaf hackberry | | SSW |
| Poison ivy | | SSW |
| Mixed woody exotics | | SSW |
| Upland | | |
| Big sagebrush | | SS |
| | Mixed grass/forb | G |
| Serviceberry | TS | |

* See text for description of plant assemblages.

** IPC Cover type codes: EHW = Emergent Herbaceous Wetland, SBW = Shore and Bottomland Wetland, SSW = Scrub-Shrub wetland, SS = Shrub Savannah, TS = Tree Savannah, G = Grassland. See technical report E.3.3-1 for a description of these cover types.

Table 2.8. Summary of canonical correspondence analysis (CCA) statistics for Brownlee Reservoir–Headwater (BH)

```

Part A: AXIS SUMMARY STATISTICS - Number of canonical axes: 3
Total variance ("inertia") in the species data: 13.8290

```

| | Axis 1 | Axis 2 | Axis 3 |
|--------------------------------|--------|--------|--------|
| Eigenvalue | 0.668 | 0.662 | 0.355 |
| Variance in species data | | | |
| % of variance explained | 4.8 | 4.8 | 2.6 |
| Cumulative % explained | 4.8 | 9.6 | 12.2 |
| Pearson Correlation, Spp-Envt* | 0.904 | 0.875 | 0.721 |
| Kendall (Rank) Corr., Spp-Envt | 0.618 | 0.628 | 0.358 |

* Correlation between sample scores for an axis derived from the species data and the sample scores that are linear combinations of the environmental variables. Set to 0.000 if axis is not canonical.

Part B: INTER-SET CORRELATIONS for 12 Environmental Variable

| Variable | Correlations | | |
|-------------|--------------|--------|--------|
| | Axis 1 | Axis 2 | Axis 3 |
| 1 MHWM | -0.398 | -0.729 | 0.074 |
| 2 MLWM | -0.398 | -0.729 | 0.074 |
| 3 SUBSTR | -0.407 | 0.594 | 0.146 |
| 4 SLOPE | -0.687 | 0.341 | -0.309 |
| 5 MAWL | -0.397 | -0.730 | 0.074 |
| 6 FP | -0.397 | -0.730 | 0.074 |
| 7 DAYSFLD | 0.594 | 0.597 | -0.211 |
| 8 FIRSTDAT | -0.107 | -0.072 | 0.198 |
| 9 LASTDATE | 0.704 | 0.398 | -0.199 |
| 10 TIMESFLD | 0.494 | 0.249 | -0.106 |
| 11 MAXDURFL | 0.610 | 0.582 | -0.211 |
| 12 MAXDURDR | -0.686 | -0.442 | 0.194 |

Table 2.9. Common plant assemblages, vegetation zones and cover types for the Brownlee Reservoir –Headwater (BH).

| Vegetation Zone | Plant Assemblage* | Cover Type** |
|--------------------------|--------------------------|---------------------|
| Barren | Common cocklebur | SBW |
| | Purslane/Tumble pigweed | SBW |
| Obligate Riparian | False indigo | SSW |
| | Coyote willow | SBW/SSW |
| | Tamarisk | SSW |
| Facultative/Transitional | False indigo | SSW |
| | Tamarisk | SSW |
| | Mixed woody exotics | SSW |
| Upland | Big sagebrush | SS |
| | Mixed grass/forb | G |

* See text for description of plant assemblages.

** IPC Cover type codes: EHW = Emergent Herbaceous Wetland, SBW = Shore and Bottomland Wetland, SSW = Scrub-Shrub wetland, G = Grassland. See Technical Report E.3.3-1 for a description of these cover types.

Table 2.10. Summary of canonical correspondence analysis (CCA) statistics for Brownlee Reservoir–Powder River Arm (BP)

```

-----
Part A:  AXIS SUMMARY STATISTICS - Number of canonical axes: 3
Total variance ("inertia") in the species data:  5.9889
          Axis 1   Axis 2   Axis 3
Eigenvalue      0.954   0.621   0.522
Variance in species data
  % of variance explained      15.9   10.4   8.7
  Cumulative % explained      15.9   26.3   35.0
Pearson Correlation, Spp-Envt*  0.994   0.901   0.854
Kendall (Rank) Corr., Spp-Envt  0.649   0.246   0.642
-----

Part B:  INTER-SET CORRELATIONS for 9 Environmental Variables
          Correlations
Variable   Axis 1   Axis 2   Axis 3
1 SUBSTR   0.052   0.011   0.724
2 SLOPE   -0.012   0.184   0.549
3 FP       0.533  -0.388  -0.020
4 DAYSFLD -0.749   0.410   0.012
5 FIRSTDAY 0.072  -0.728   0.073
6 LASTDAY -0.989  -0.067   0.024
7 TIMESFLD -0.676  -0.286  -0.007
8 MAXFLD  -0.778   0.414  -0.023
9 MAXDRY   0.977  -0.005  -0.023
-----

```

Table 2.11. Common plant assemblages, vegetation zones and cover types for the Brownlee Reservoir–Powder River Arm (BP).

| Vegetation Zone | Plant Assemblage* | Cover Type** |
|--------------------------|--------------------------|---------------------|
| Barren | Annual bluegrass | SBW |
| | Common cocklebur | SBW |
| | Purslane/Tumble pigweed | SBW |
| | Water smartweed | SBW |
| | Witchgrass | SBW |
| Obligate Riparian | Coyote willow | SBW/SSW |
| | Reed canarygrass | EHW |
| Facultative/Transitional | Coyote willow | SSW |
| Upland | Mixed grass/forb | G |

* See text for description of plant assemblages.

** IPC Cover type codes: EHW = Emergent Herbaceous Wetland, SBW = Shore and Bottomland Wetland, SSW = Scrub-Shrub wetland, G = Grassland. See Technical Report E.3.3-1 for a description of these cover types.

Table 2.12. Summary of canonical correspondence analysis (CCA) statistics for Hells Canyon Reservoir–Oxbow Bypass (OB).

```

-----
Part A: AXIS SUMMARY STATISTICS - Number of canonical axes: 3
Total variance ("inertia") in the species data: 11.5608
      Eigenvalue      Axis 1      Axis 2      Axis 3
Variance in species data
  % of variance explained      7.5      5.9      5.5
  Cumulative % explained      7.5      13.4      18.9
Pearson Correlation, Spp-Envt*      0.976      0.921      0.919
Kendall (Rank) Corr., Spp-Envt      0.785      0.664      0.695
-----

Part B: INTER-SET CORRELATIONS for 9 Environmental Variables
      Correlations
      Variable      Axis 1      Axis 2      Axis 3
1 SUBSTR      0.090      0.327      0.815
2 SLOPE      0.005      -0.153      0.435
3 FP      -0.938      0.022      0.196
4 DAYSFLD      0.695      -0.242      -0.386
5 FIRSTDAY      0.028      0.079      -0.041
6 LASTDAY      0.715      -0.073      -0.441
7 TIMESFLD      0.566      0.334      -0.447
8 MAXFLD      0.605      -0.576      -0.234
9 MAXDRY      -0.715      0.101      0.433
-----

```

Table 2.13. Common plant assemblages, vegetation zones and cover types for the Hells Canyon Reservoir–Oxbow Bypass (OB).

| Vegetation Zone | Plant Assemblage* | Cover Type** |
|--------------------------|-------------------------|--------------|
| Barren | Common cocklebur | SBW |
| | Purslane/Tumble pigweed | SBW |
| Obligate Riparian | False indigo | SSW |
| | Coyote willow | SSW |
| Facultative/Transitional | False indigo | SSW |
| | Netleaf hackberry | SSW |
| Upland | Mixed grass/forb | G |

* See text for description of plant assemblages.

** IPC Cover type codes: EHW = Emergent Herbaceous Wetland, SBW = Shore and Bottomland Wetland, SSW = Scrub-Shrub wetland, SS = Shrub Savannah, TS = Tree Savannah, G = Grassland. See technical report E.3.3-1 for a description of these cover types.

Table 2.14. Estimated ages for select trees in the Weiser Reach (WR). Ages were based on ring-counts of tree cores collected along the transects.

| Common Name | Species | N | Mean Age | SD |
|-------------------|------------------------------|---|----------|------|
| American elm | <i>Ulmus Americana</i> | 3 | 43 | 10.1 |
| European willow | <i>Salix alba</i> | 9 | 30 | 12.0 |
| Plains cottonwood | <i>Populus deltoids</i> | 2 | 34 | 24.5 |
| Russian olive | <i>Eleagnus angustifolia</i> | 3 | 19 | 5.3 |
| Salt cedar | <i>Tamarix complex</i> | 3 | 10 | 1.0 |
| Silver maple | <i>Acer saccharinum</i> | 3 | 40 | 11.5 |

Table 2.15. Summary of canonical correspondence analysis (CCA) statistics for Weiser Reach (WR)

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-----
Part A: AXIS SUMMARY STATISTICS - Number of canonical axes: 3
Total variance ("inertia") in the species data: 16.0799
Eigenvalue                Axis 1    Axis 2    Axis 3
Variance in species data
  % of variance explained    4.1      2.9      1.7
  Cumulative % explained     4.1      7.0      8.8
Pearson Correlation, Spp-Envt* 0.924    0.868    0.728
Kendall (Rank) Corr., Spp-Envt 0.771    0.614    0.519

* Correlation between sample scores for an axis derived from the
species data and the sample scores that are linear combinations of
the environmental variables. Set to 0.000 if axis is not canonical.

-----
Part B: INTER-SET CORRELATIONS for 6 Environmental Variables.
              Correlations
Variable      Axis 1  Axis 2  Axis 3
1 SUBSTR      0.464  -0.148  0.053
2 SLOPE       -0.155  -0.616  0.481
3 EMAWL       0.796   0.393  0.147
4 EBF         0.779   0.352  0.167
5 EMaxP       0.562   0.590  0.290
6 EAveP       0.737   0.463  0.174
-----

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Table 2.16. Summary of canonical correspondence analysis (CCA) statistics for Snake River Reach (SN).

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Part A: AXIS SUMMARY STATISTICS - Number of canonical axes: 3
Total variance ("inertia") in the species data: 31.4535
Eigenvalue                Axis 1   Axis 2   Axis 3
Variance in species data  0.556   0.295   0.169
  % of variance explained  1.8     0.9     0.5
  Cumulative % explained  1.8     2.7     3.2
Pearson Correlation, Spp-Envt*  0.811   0.679   0.516
Kendall (Rank) Corr., Spp-Envt  0.616   0.397   0.299

* Correlation between sample scores for an axis derived from the species
  data and the sample scores that are linear combinations of the
  environmental variables. Set to 0.000 if axis is not canonical.

-----
Part B: INTER-SET CORRELATIONS for 7 Environmental Variables
              Correlations
Variable     Axis 1  Axis 2  Axis 3
1 SUBSTR    -0.371  0.532 -0.135
2 SLOPE      0.022  0.462  0.280
3 EfromMin   0.646  0.314 -0.030
4 EfromMea   0.673  0.290 -0.037
5 EfromMAW   0.735  0.222 -0.047
6 EfromMea   0.786  0.053 -0.005
7 EfromMax   0.728 -0.052  0.021
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Figure 2.1. Annual variation in flow at Weiser Gage (maximum, average, and minimum daily) from 1911 to 1999.

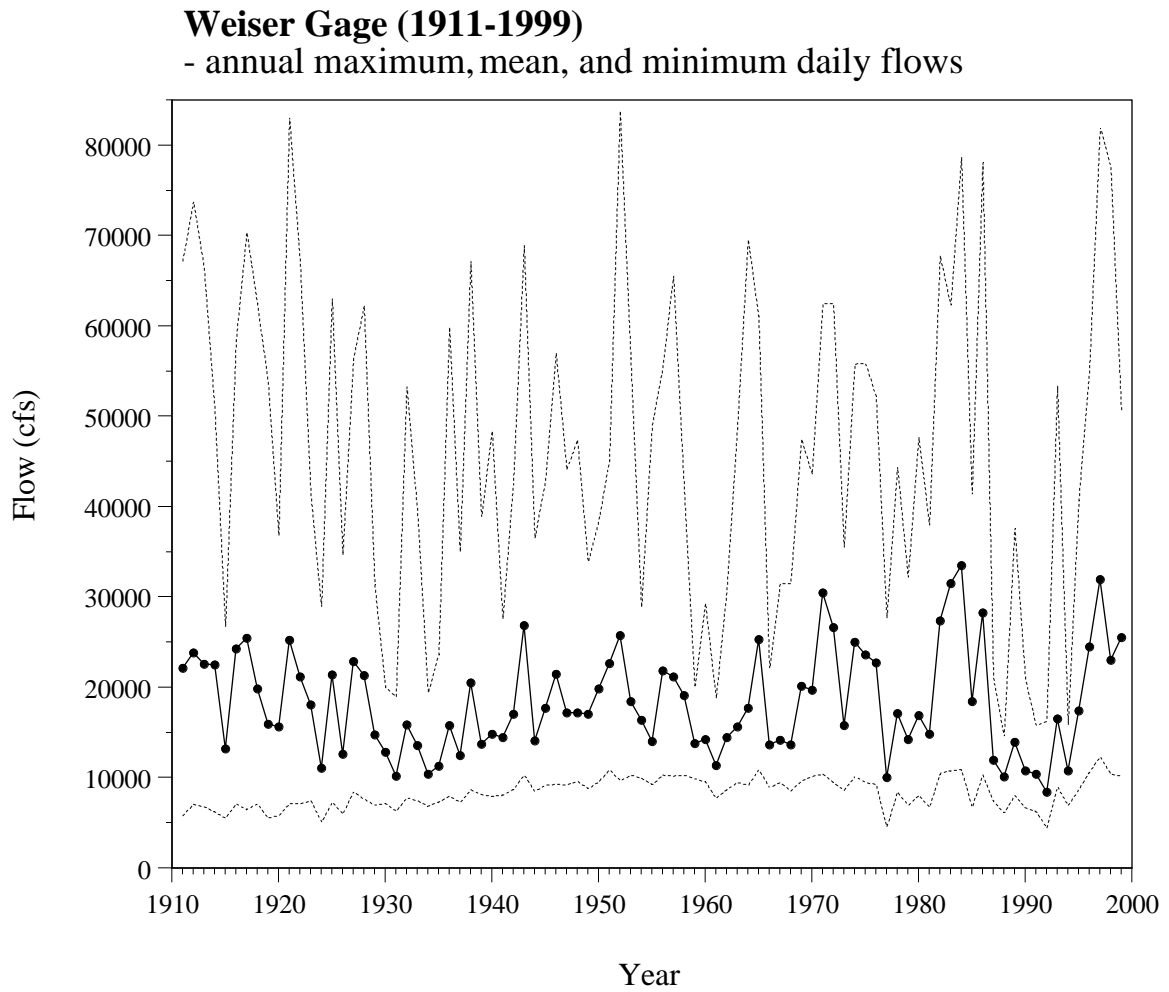


Figure 2.2. Seasonal variation in flow at Weiser Gage (daily mean ± 1 SD) from 1911 to 1921 (pre-Swan Falls Dam), 1948 to 1958 (pre-Brownlee Dam), and 1990 to 1999 (recent).

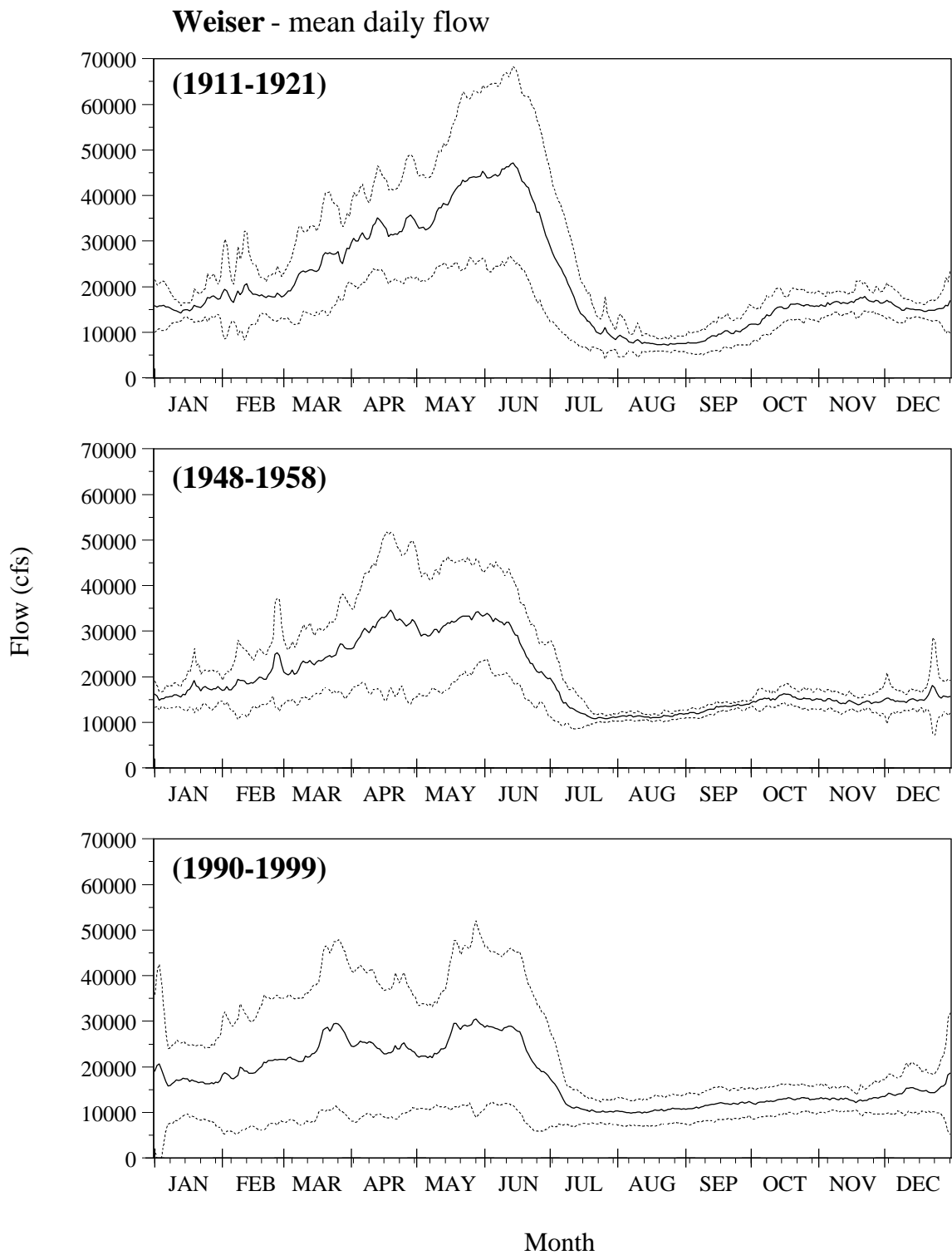


Figure 2.3. Seasonal variation in flow at Weiser Gage (daily mean \pm 1 SD) from 1970 to 1974, 1984 to 1989, and 1994 to 1999.

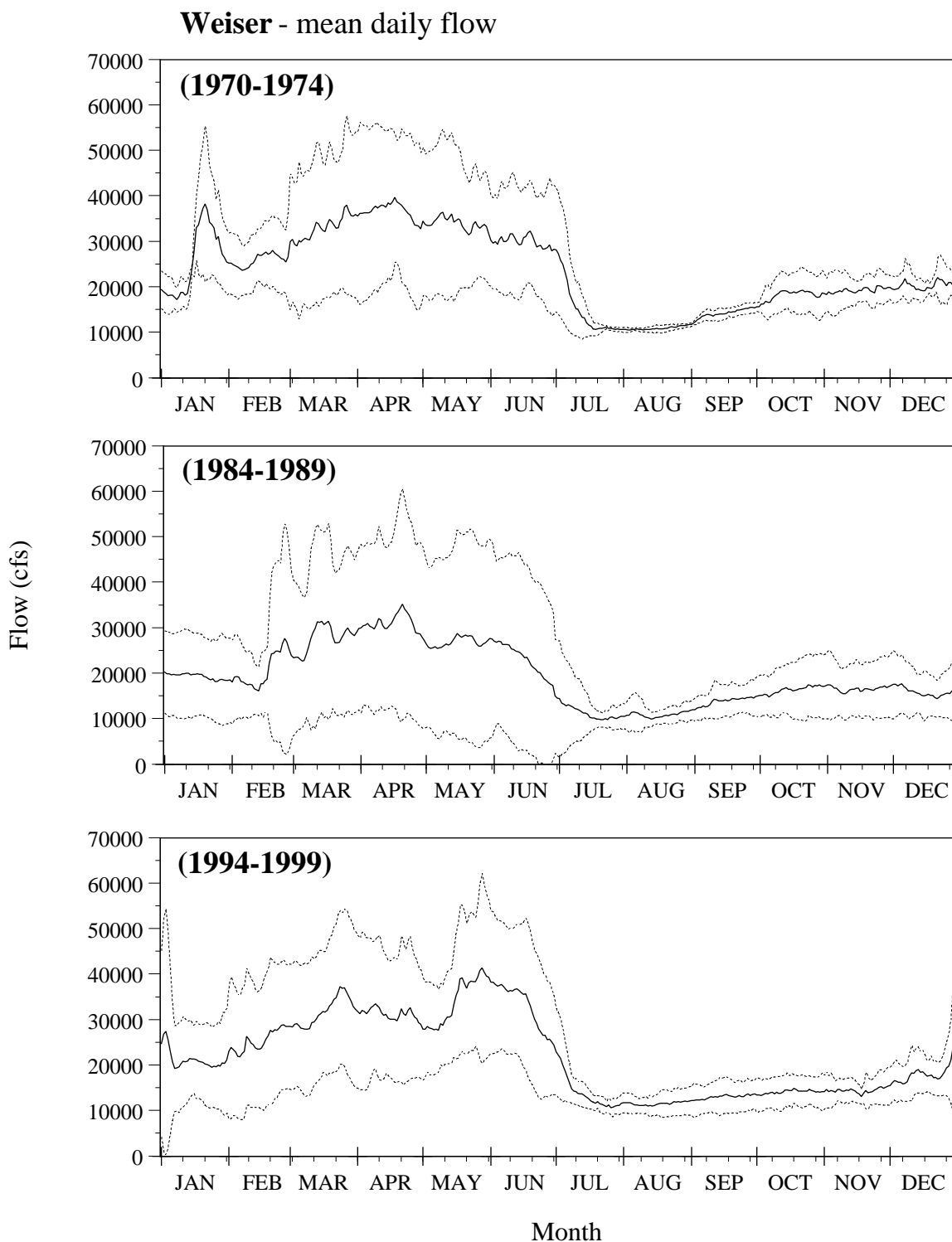


Figure 2.4. Schematic of a standard belt-transect with nested herb (H), shrub (S), and tree (T) quadrats.

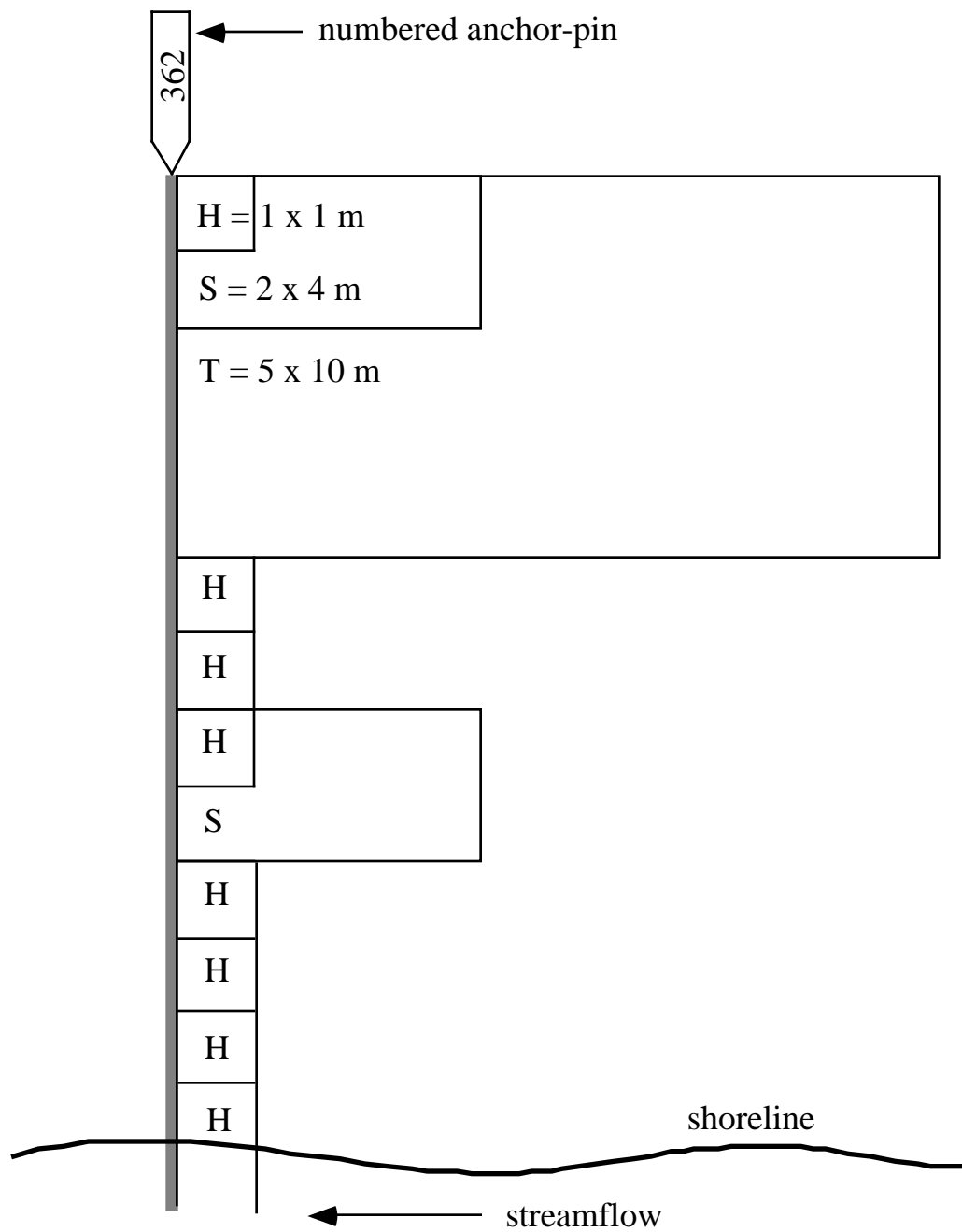


Figure 2.5. Annual variation in water levels (maximum, average, and minimum daily) at Brownlee Reservoir from 1958 to 1999.

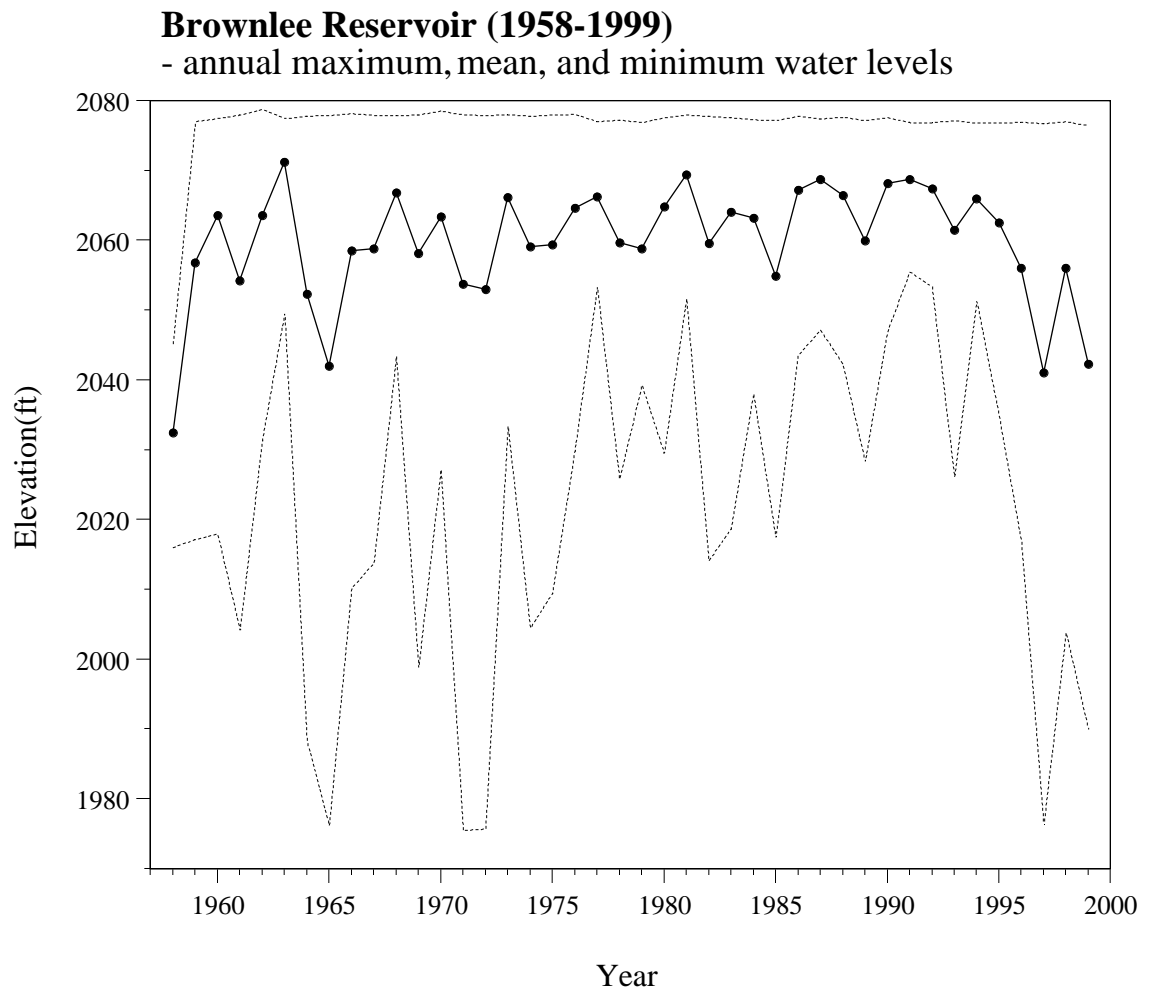


Figure 2.6. Seasonal variation in water levels for Brownlee Reservoir (daily mean \pm 1 SD) from 1970 to 1974, 1984 to 1989, and 1994 to 1999.

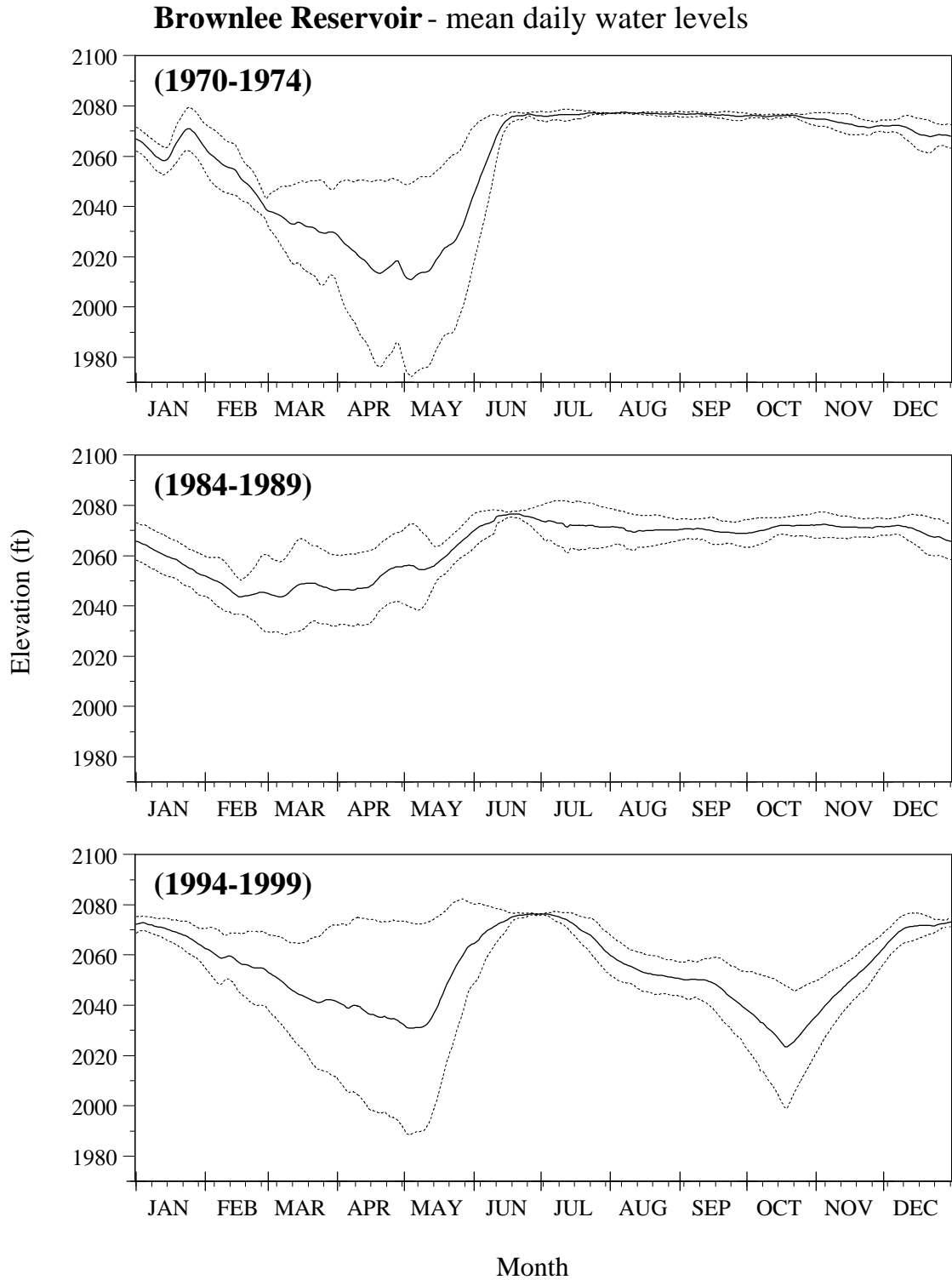


Figure 2.7. Annual variation in water levels (maximum, average, and minimum daily) for Oxbow Reservoir from 1961 to 2000.

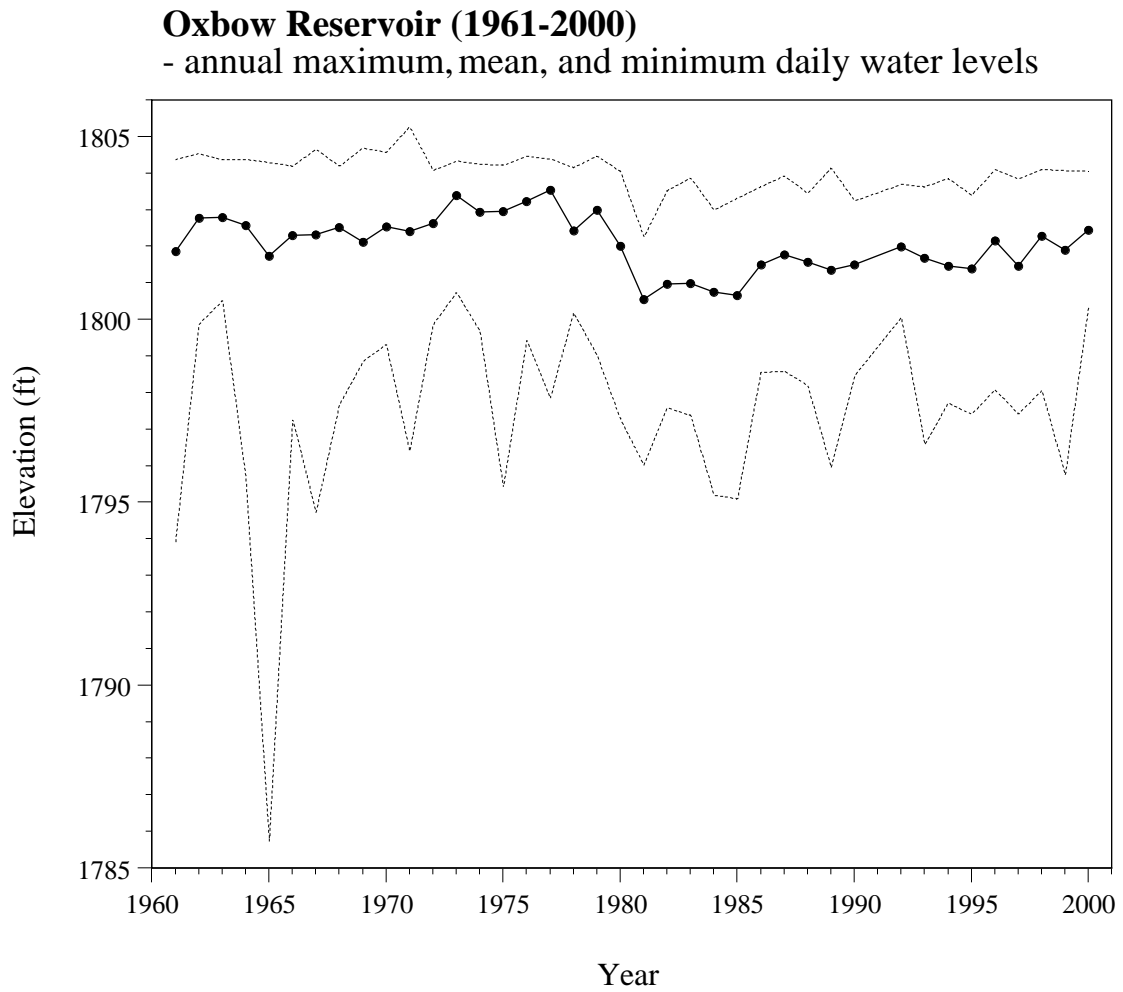


Figure 2.8. Seasonal variation in water levels for Oxbow Reservoir (daily mean \pm 1 SD) from 1970 to 1974, 1984 to 1989, and 1994 to 1999.

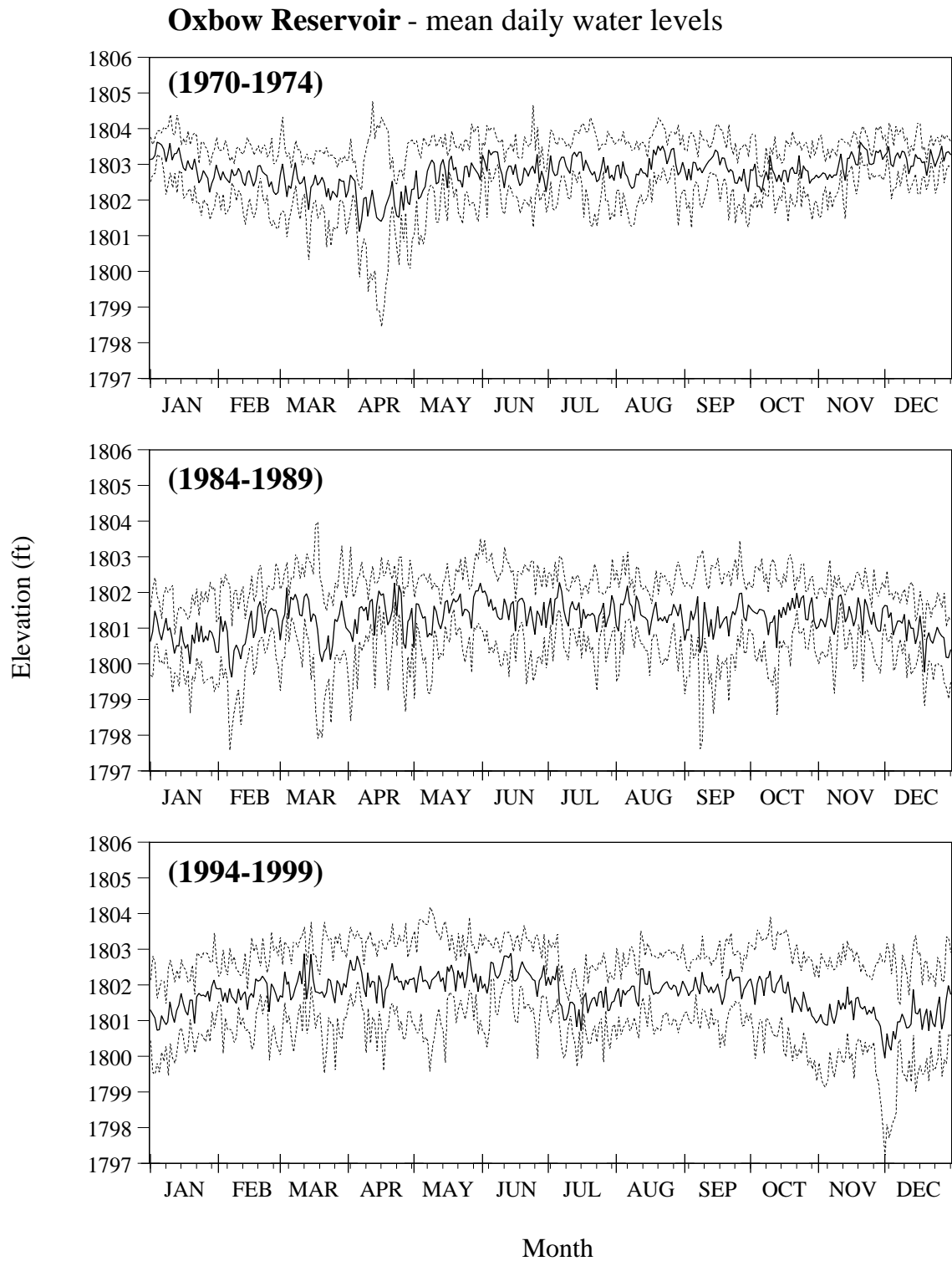


Figure 2.9. Annual variation in water levels (maximum, average, and minimum daily) for Hells Canyon Reservoir from 1967 to 1999.

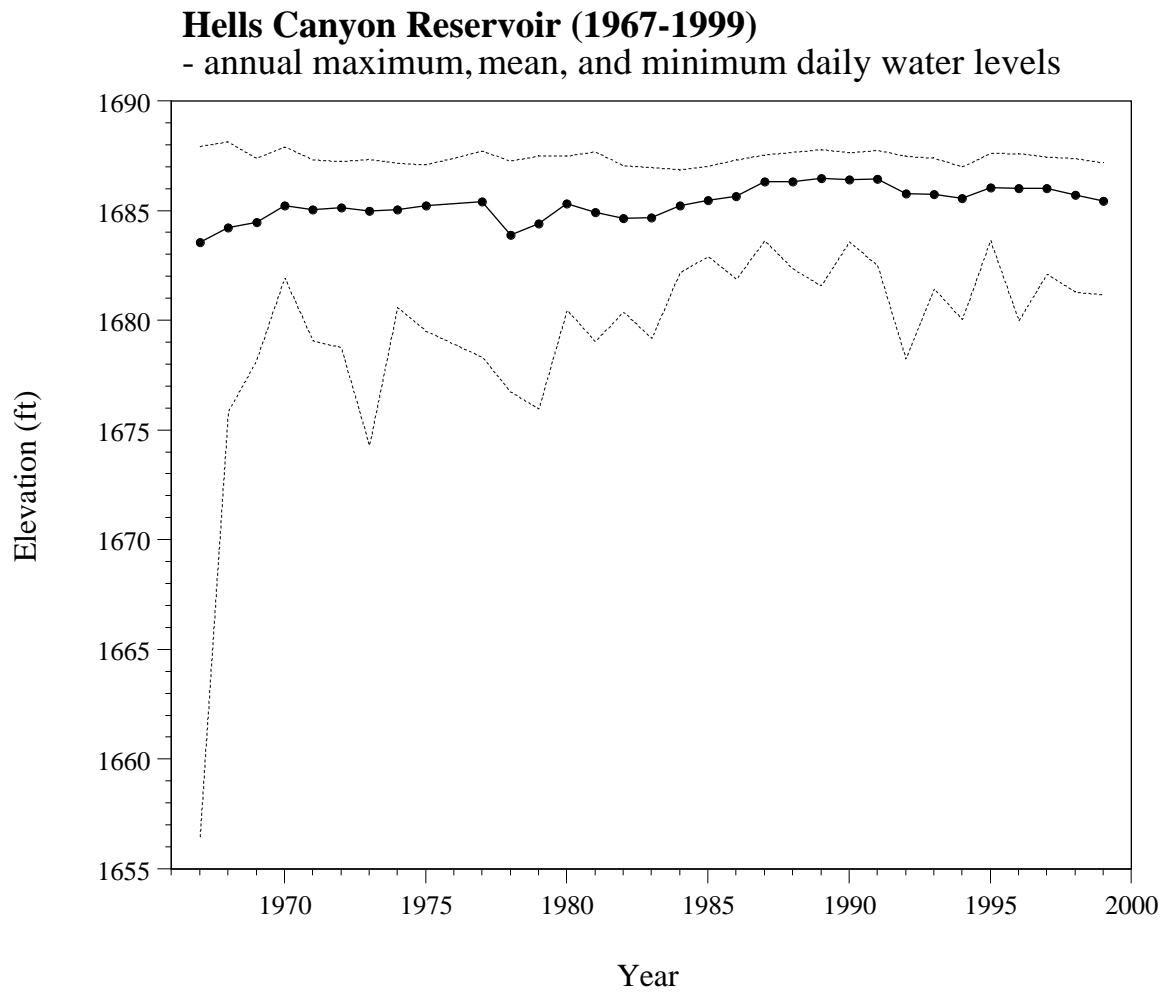


Figure 2.10. Seasonal variation in water levels for Hells Canyon Reservoir (daily mean \pm 1 SD) from 1970 to 1974, 1984 to 1989, and 1994 to 1999.

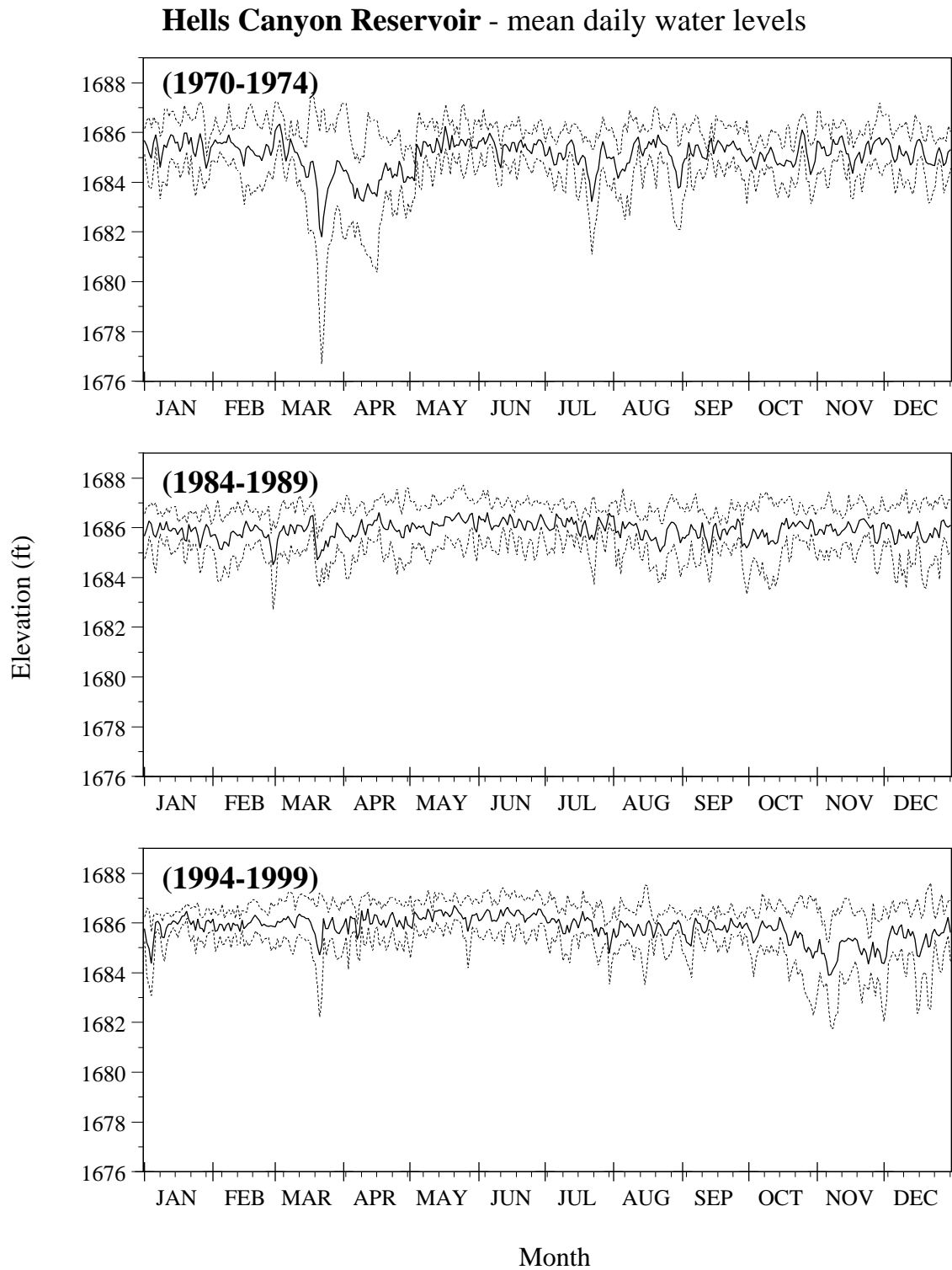


Figure 2.11. Elevational distribution of shoreline vegetation along Brownlee Reservoir - Main (BM) from 1998 to 2000 (species in each category are listed in Appendix 2-1).

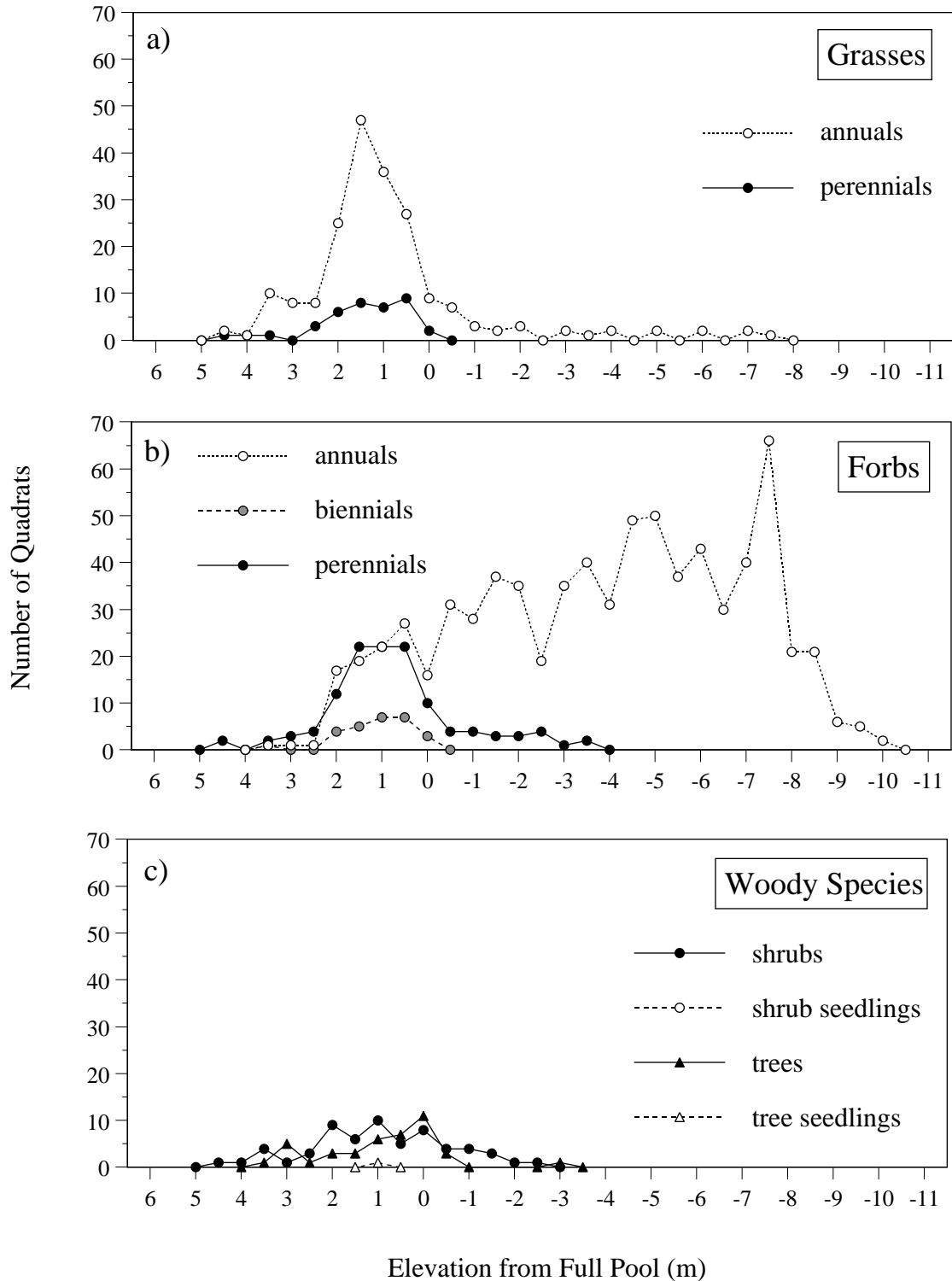


Figure 2.12. Relative cover indices for shoreline vegetation along the three reaches of Brownlee Reservoir (species in each category are listed in Appendix 2-1).

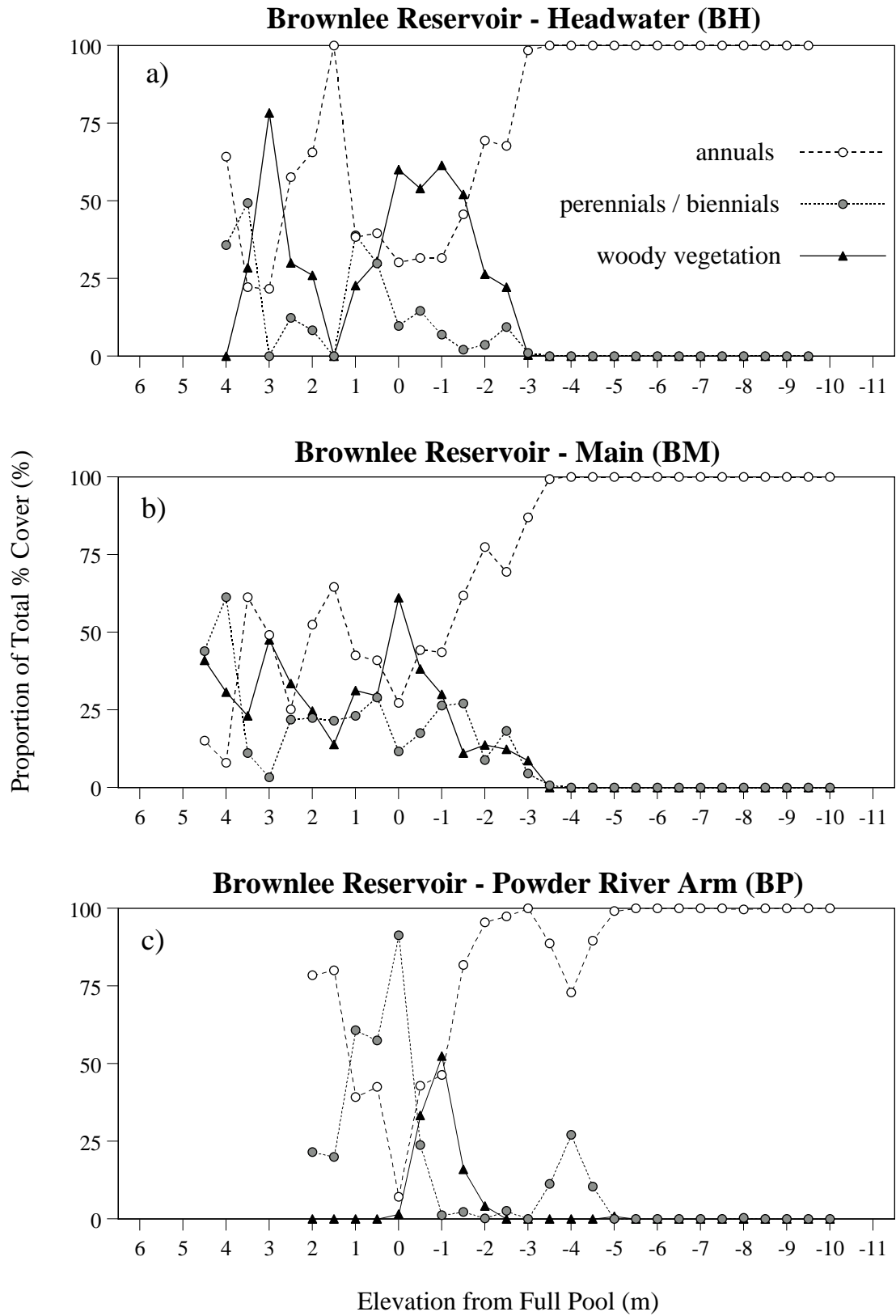


Figure 2.13. Average cover indices for shoreline vegetation along the three Brownlee Reservoir reaches (species in each category are listed in Appendix 2.1.).

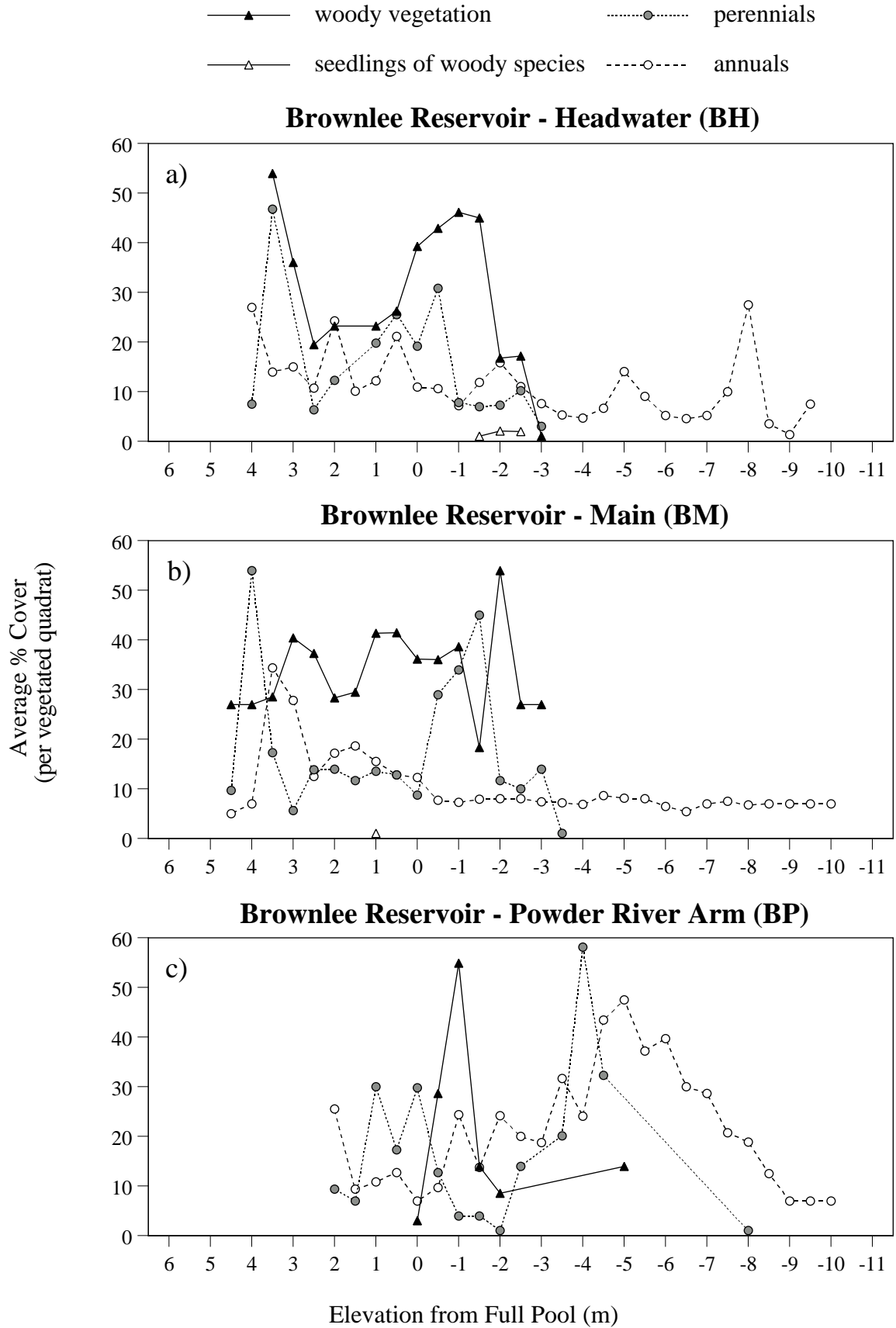


Figure 2.14. Substrate affinities of shoreline vegetation along the Brownlee Reservoir - Headwater (BH), Brownlee Reservoir - Main (BM), and Brownlee Reservoir - Powder River Arm (BP). The number of quadrats in each sample is indicated (species in each category are listed in Appendix 2.1.).

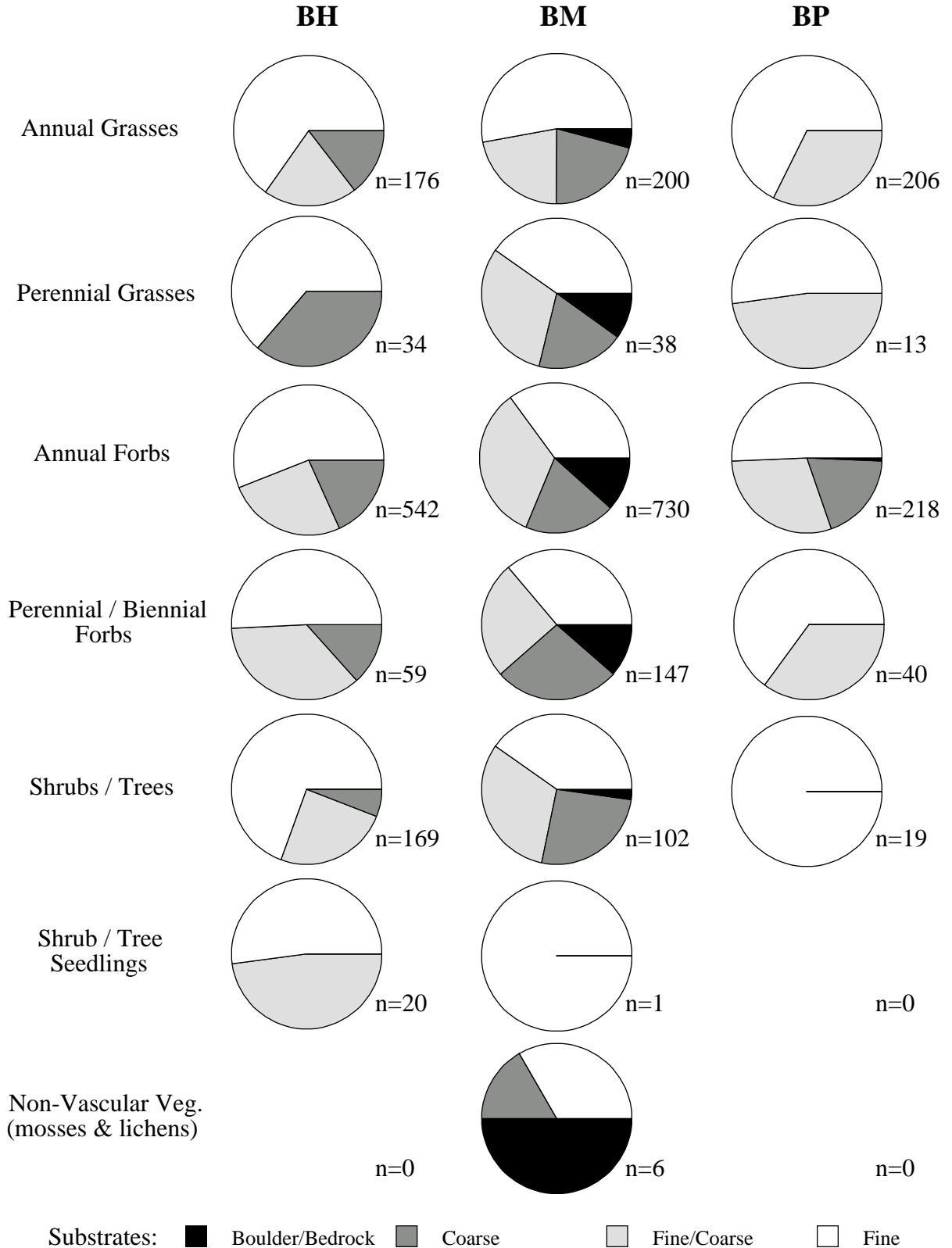


Figure 2.15. Habitat affinities of shoreline vegetation along the Brownlee Reservoir - Headwater (BH), Brownlee Reservoir - Main (BM), and Brownlee Reservoir - Powder River Arm (BP). The number of quadrats in each sample is indicated (species in each category are listed in Appendix 2-1).

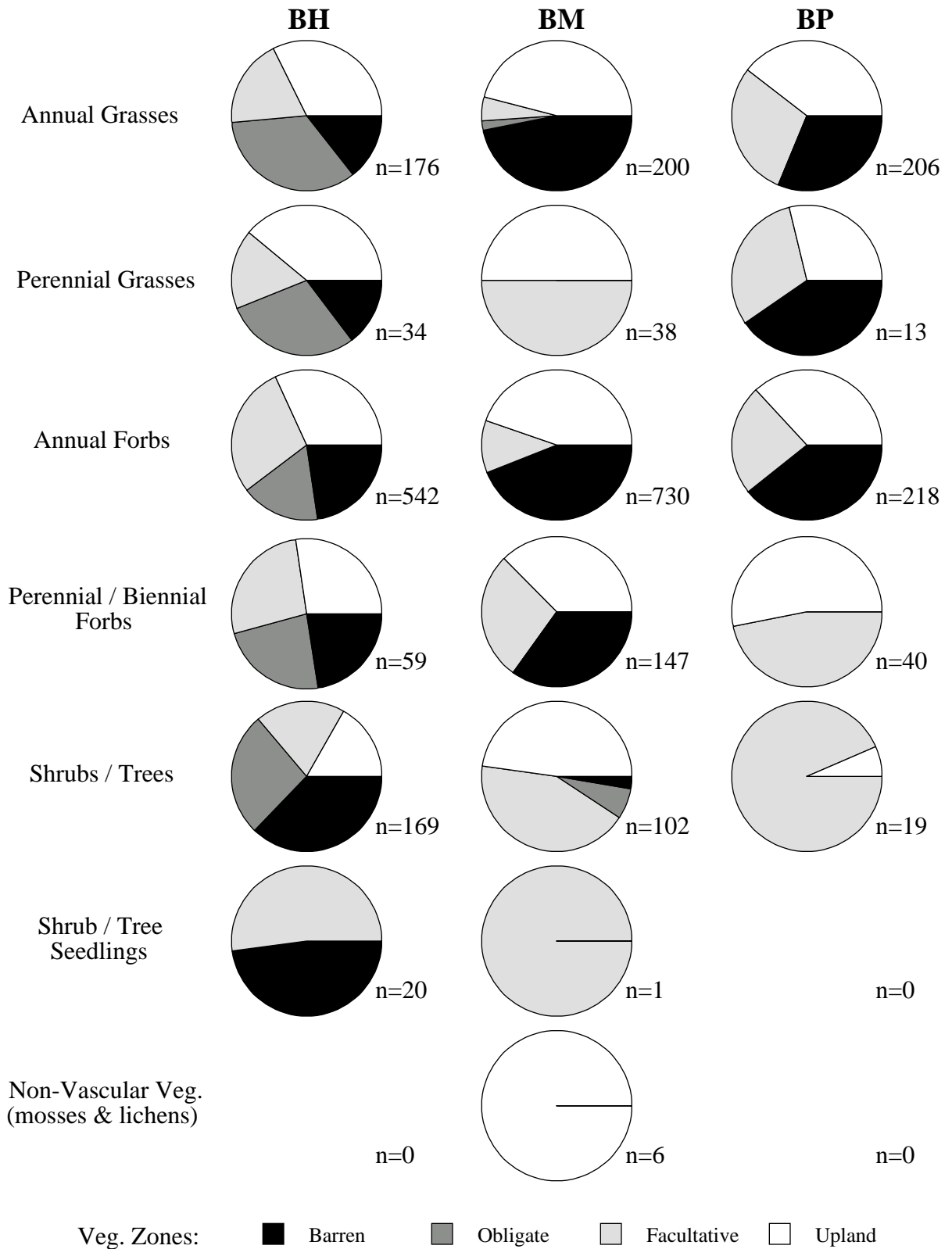


Figure 2.16. Canonical correspondence analysis (CCA) ordination of sample plots for Brownlee Reservoir - Main (BM). Each point represents one quadrat. Abbreviations are defined in Table 2.9.

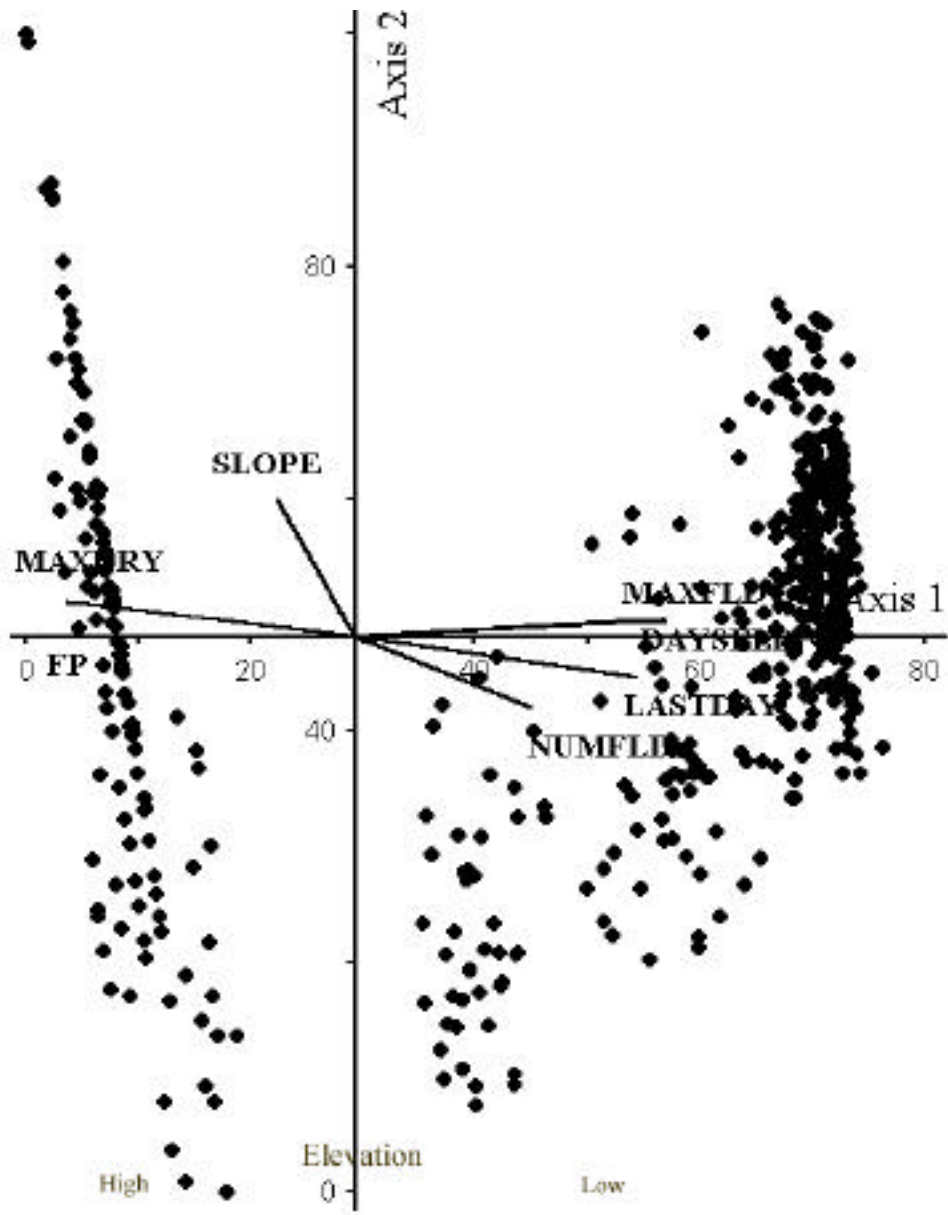


Figure 2.17. Canonical correspondence analysis (CCA) ordination of plant species for Brownlee Reservoir - Main (BM). Abbreviations of species are defined in Appendix 2.1.

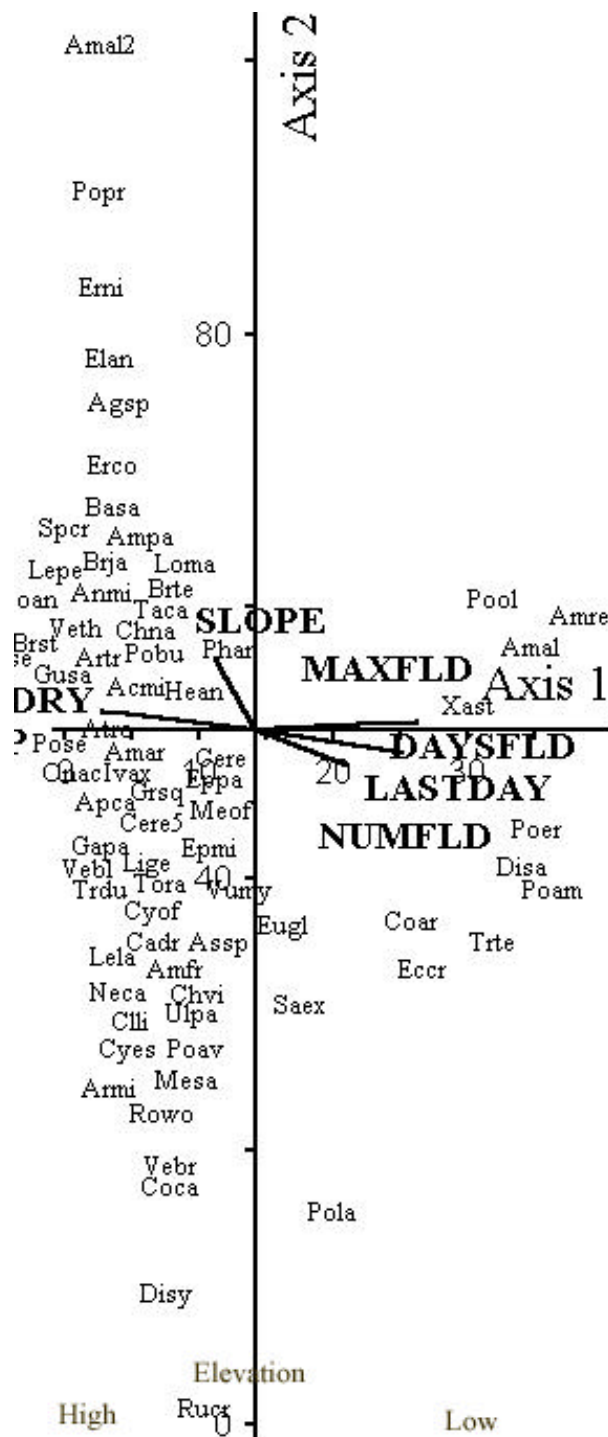


Figure 2.18. Schematic of vertical zonation of vegetation types for the shorelines along Brownlee Reservoir - Main.

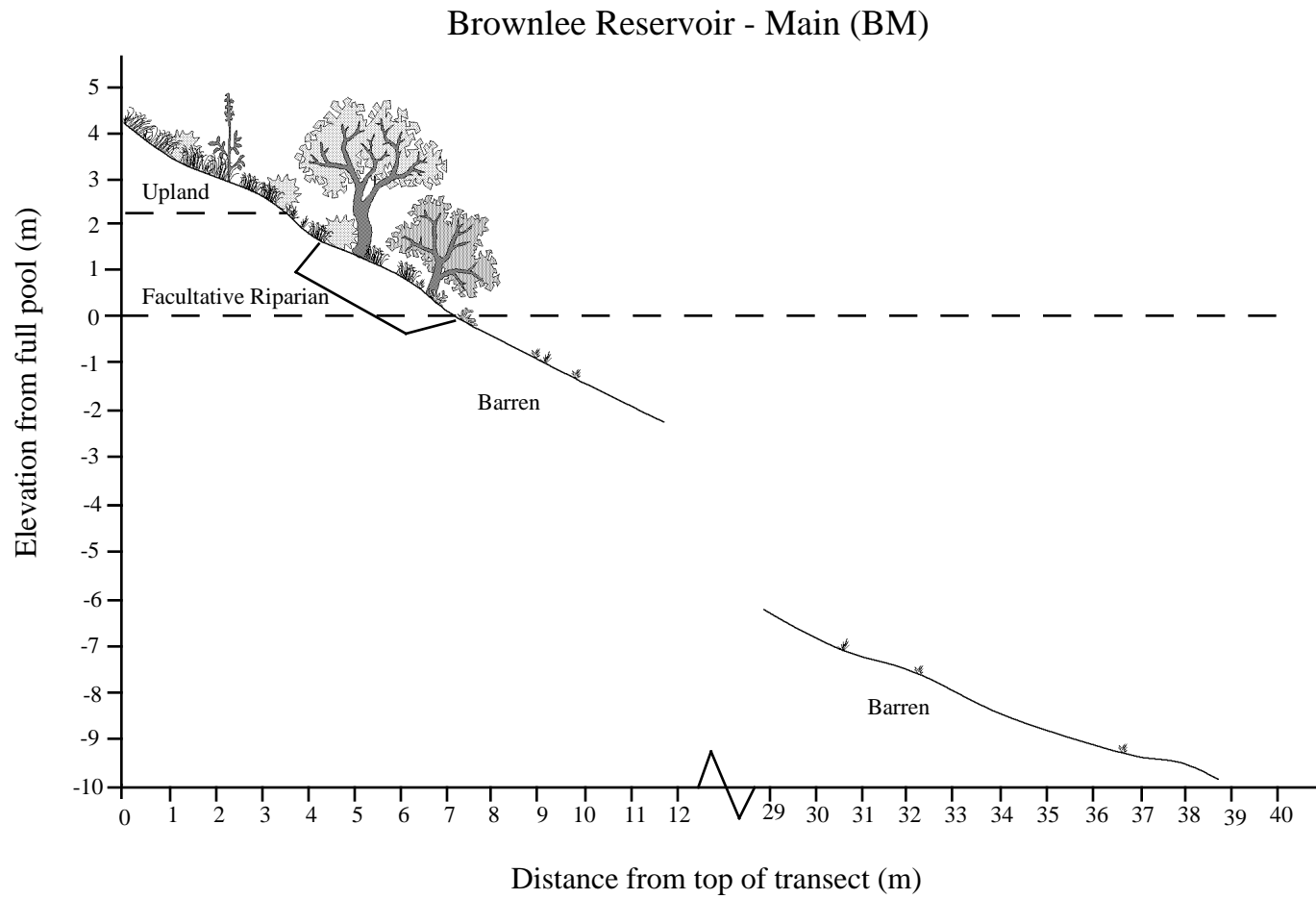


Figure 2.19. Elevational distribution of shoreline vegetation along the Oxbow Reservoir - Main (OB) from 1998 to 2000 (species in each category are listed in Appendix 2.1.).

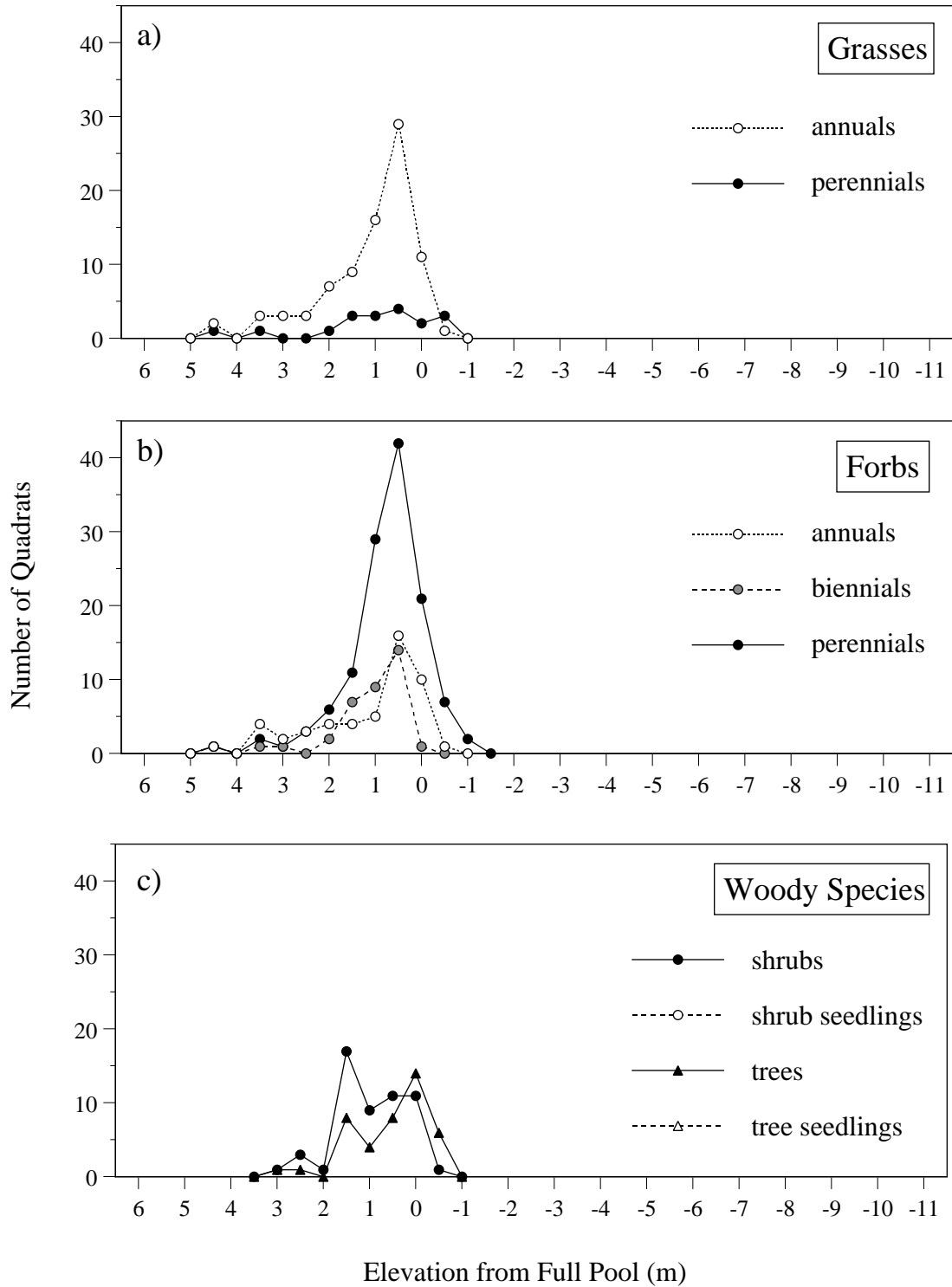


Figure 2.20. Elevational distribution of shoreline vegetation along the Hells Canyon Reservoir - Main (HM) from 1998 to 2000 (species in each category are listed in Appendix 2.1.).

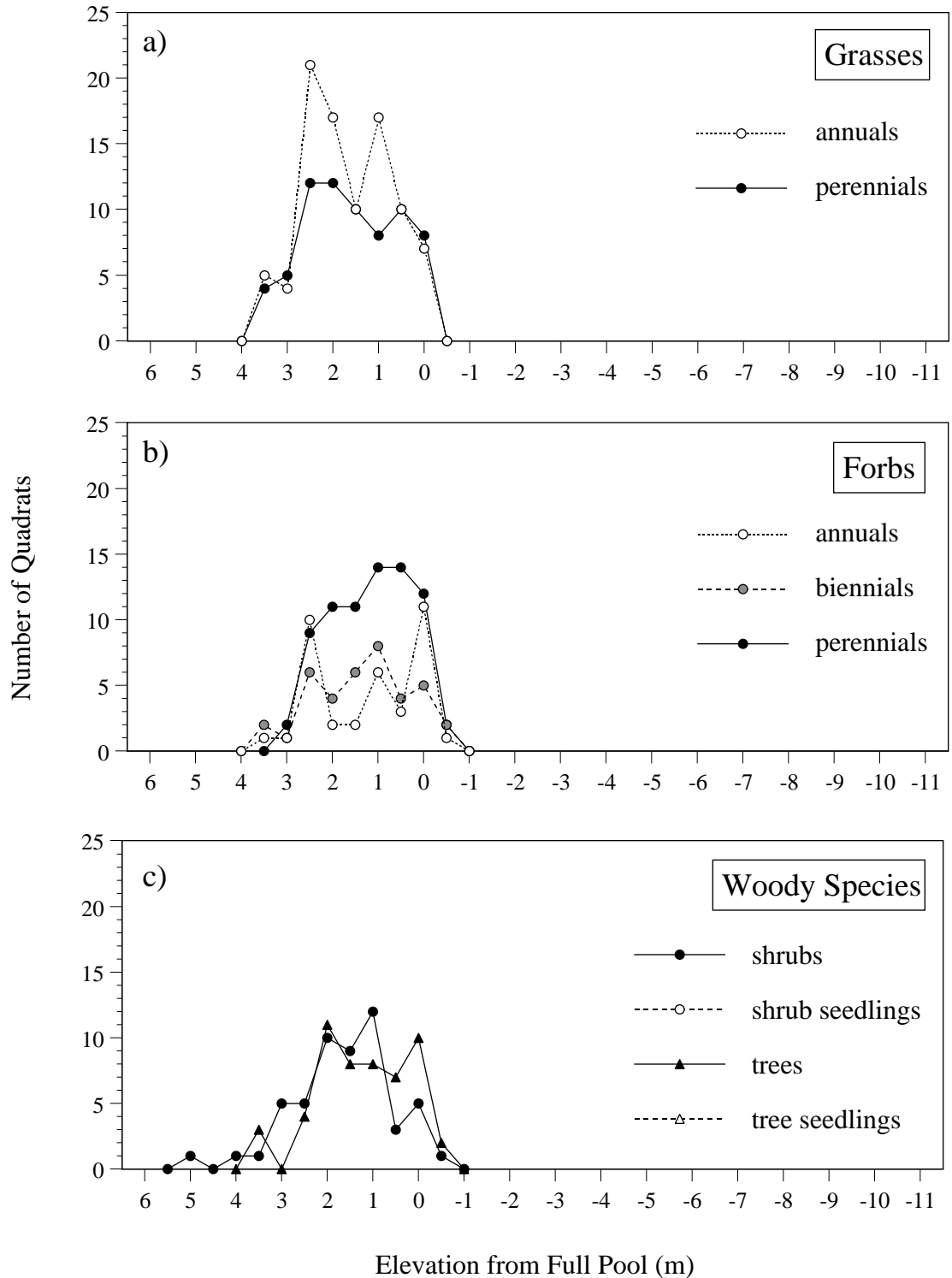


Figure 2.21. Relative cover indices for shoreline vegetation along the Oxbow Bypass (OB) and Main reaches of the Hells Canyon (HM) and Oxbow (OM) reservoirs from 1998 to 2000 (species in each category are listed in Appendix 2.1.).

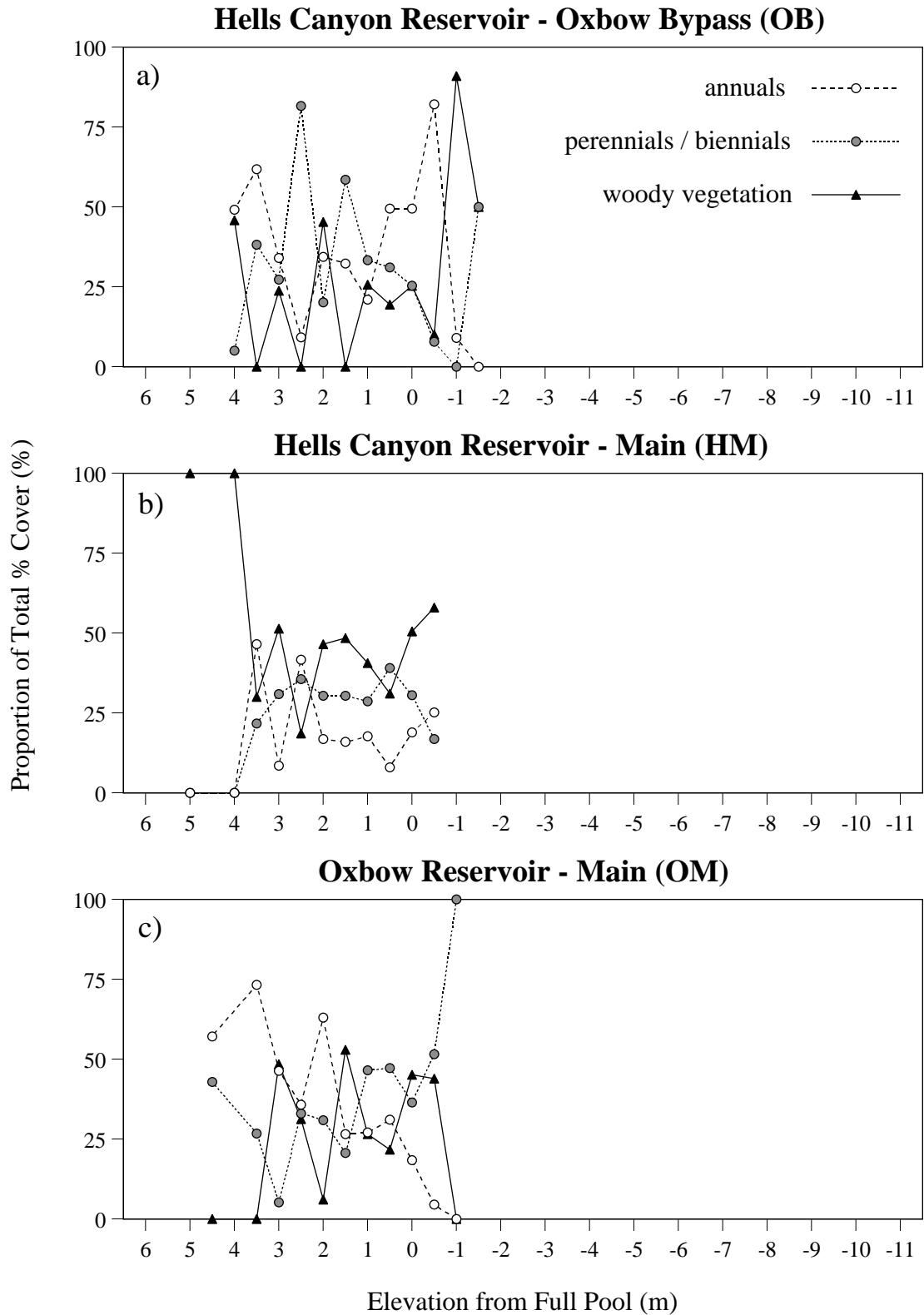


Figure 2.22. Average cover indices for shoreline vegetation along the Oxbow Bypass (OB) and Main reaches of Hells Canyon (HM) and Oxbow (OM) reservoirs (note that the scales of the y-axes differ) (species in each category are listed in Appendix 2.1.).

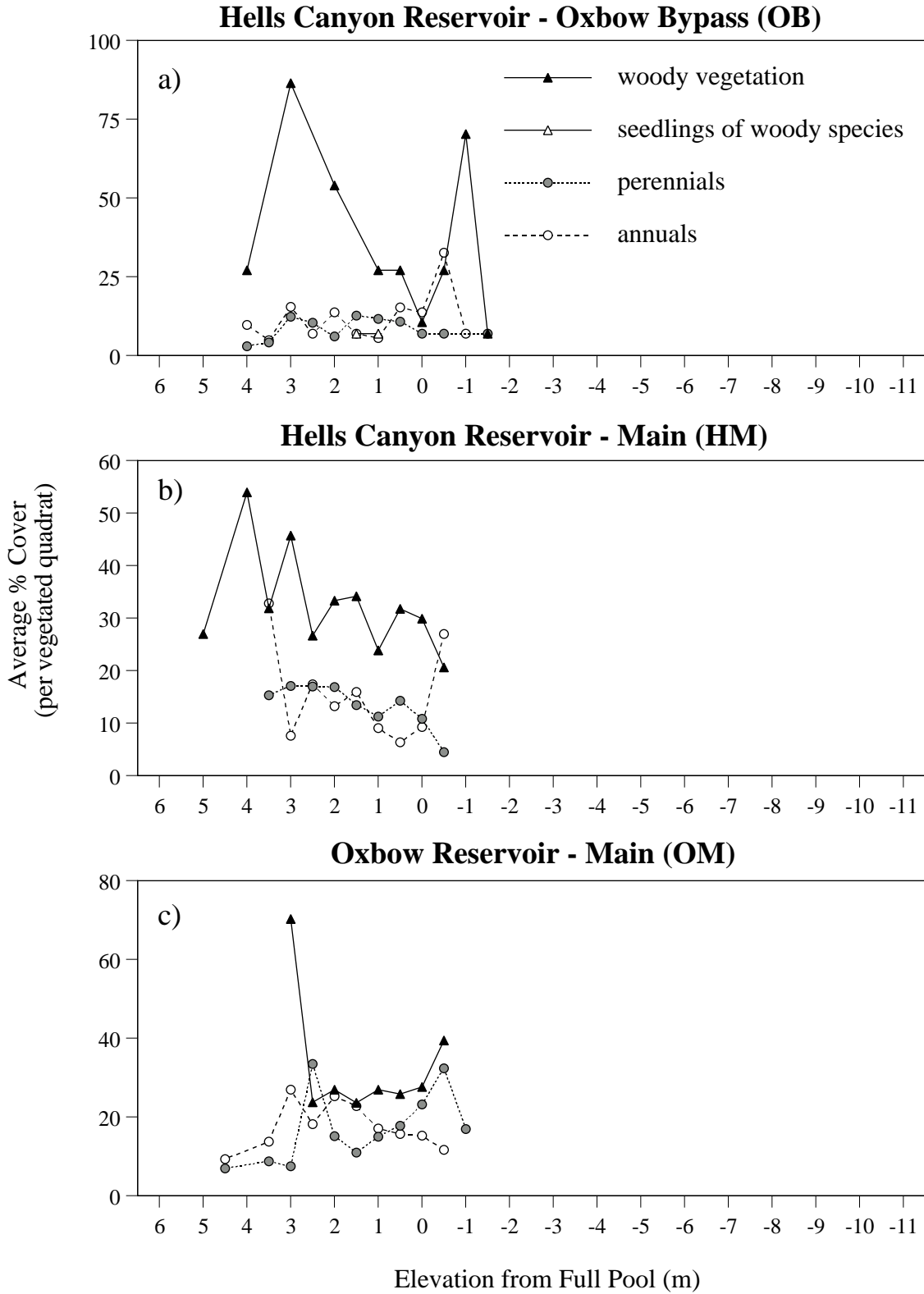


Figure 2.23. Substrate affinities of shoreline vegetation along the Oxbow Reservoir - Main (OM), Hells Canyon Reservoir - Main (HM), and the Hells Canyon - Oxbow Bypass (OB). The number of quadrats in each sample is indicated (species in each category are listed in Appendix 2.1.).

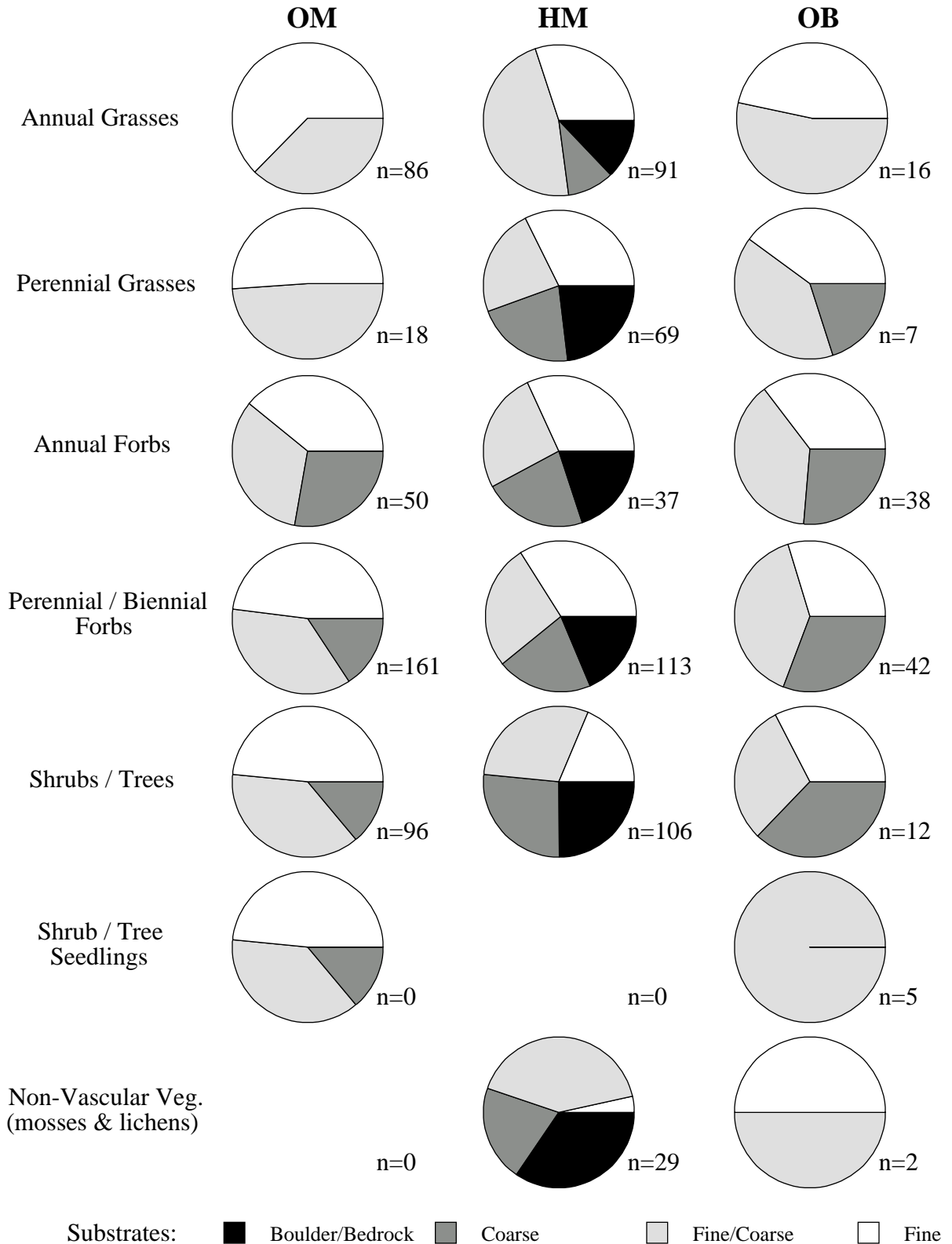


Figure 2.24. Habitat affinities of shoreline vegetation along the Oxbow Reservoir - Main (OM), Hells Canyon Reservoir - Main (HM), and Hells Canyon Reservoir - Oxbow Bypass (OB). The number of quadrats in each sample is indicated (species in each category are listed in Appendix 2.1).

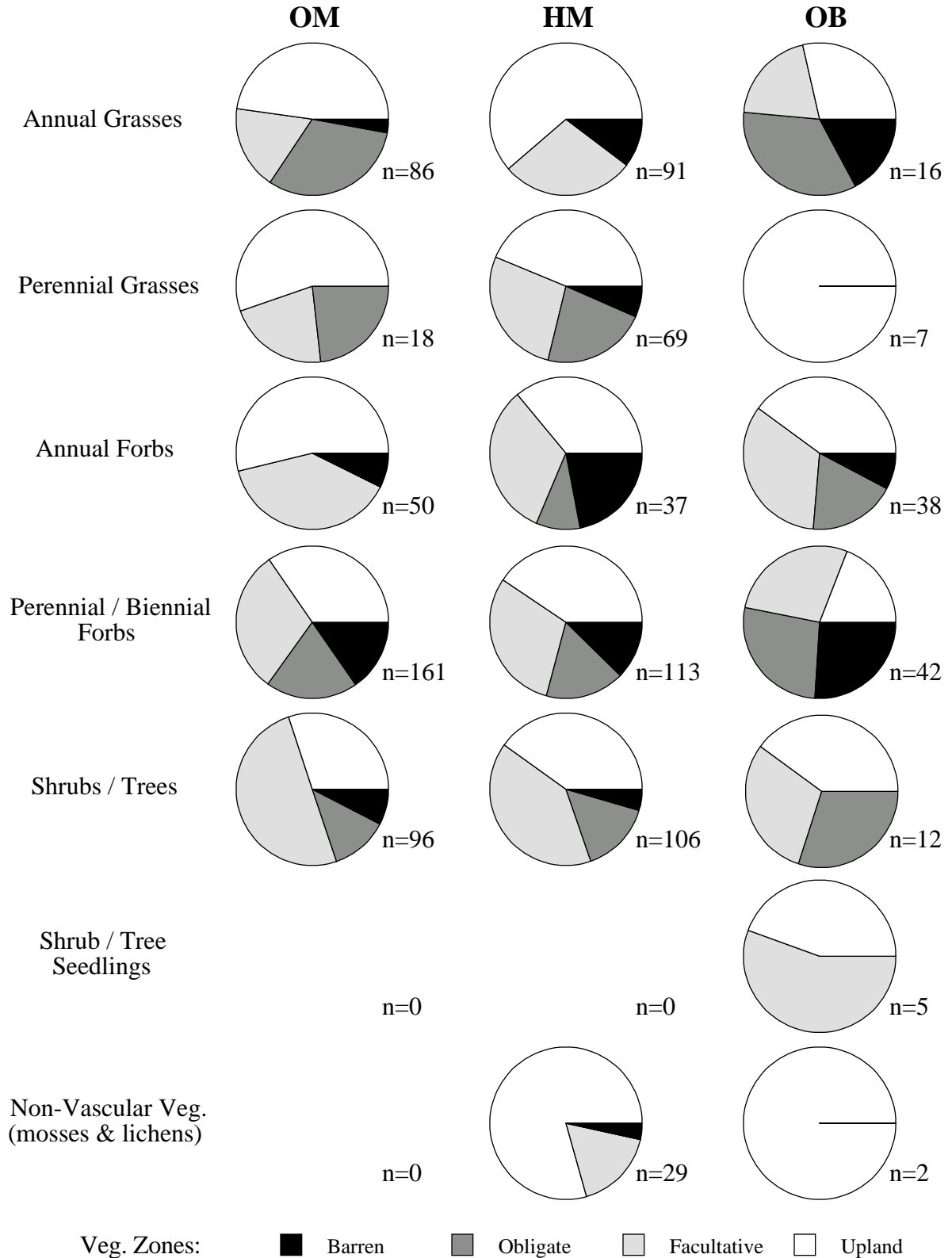


Figure 2.25. Canonical correspondence analysis (CCA) ordination of sample plots for the main reaches of Oxbow and Hells Canyon reservoirs (OM & HM). Each point represents one quadrat. Abbreviations are defined in Table 2.9.

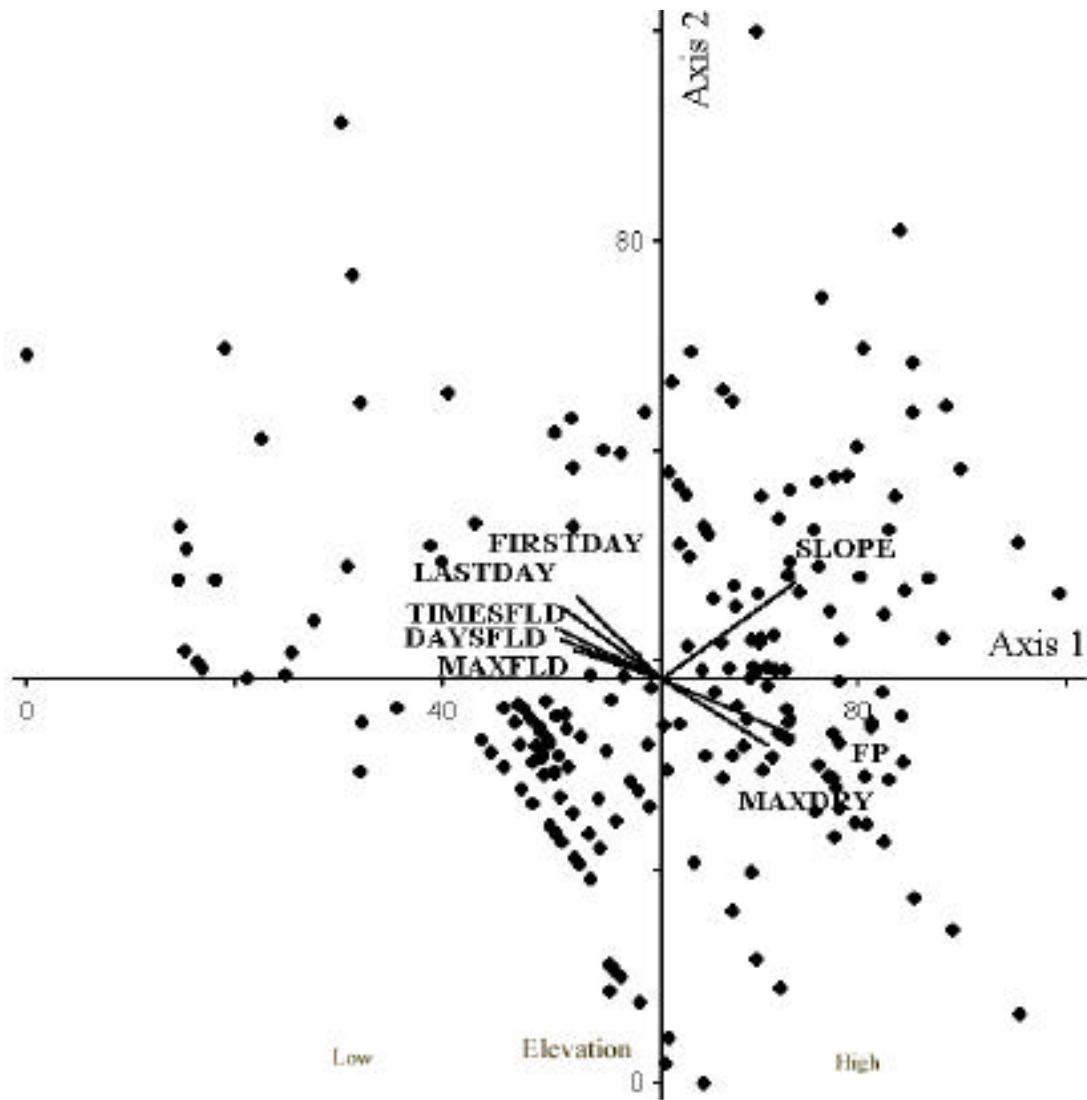


Figure 2.26. Canonical correspondence analysis (CCA) ordination of plant species for the main reaches of Oxbow and Hells Canyon reservoirs (OM & HM). Abbreviations of species are defined in Appendix 2.1.

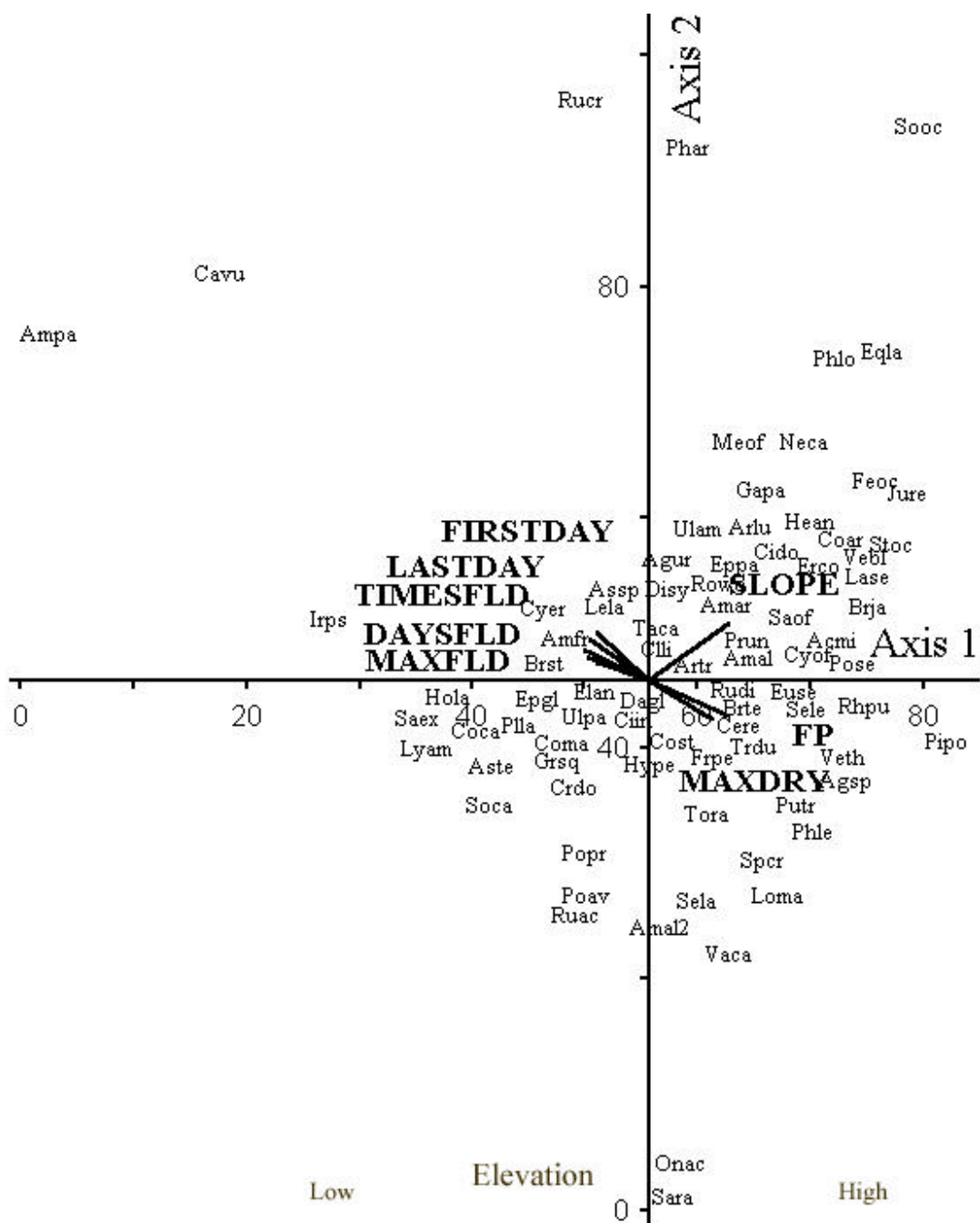


Figure 2.27. Schematics of vertical zonation of vegetation types for the shorelines along the Main reaches of the Oxbow (OM) and Hells Canyon (HM) reservoirs, and along the Oxbow Bypass (OB).

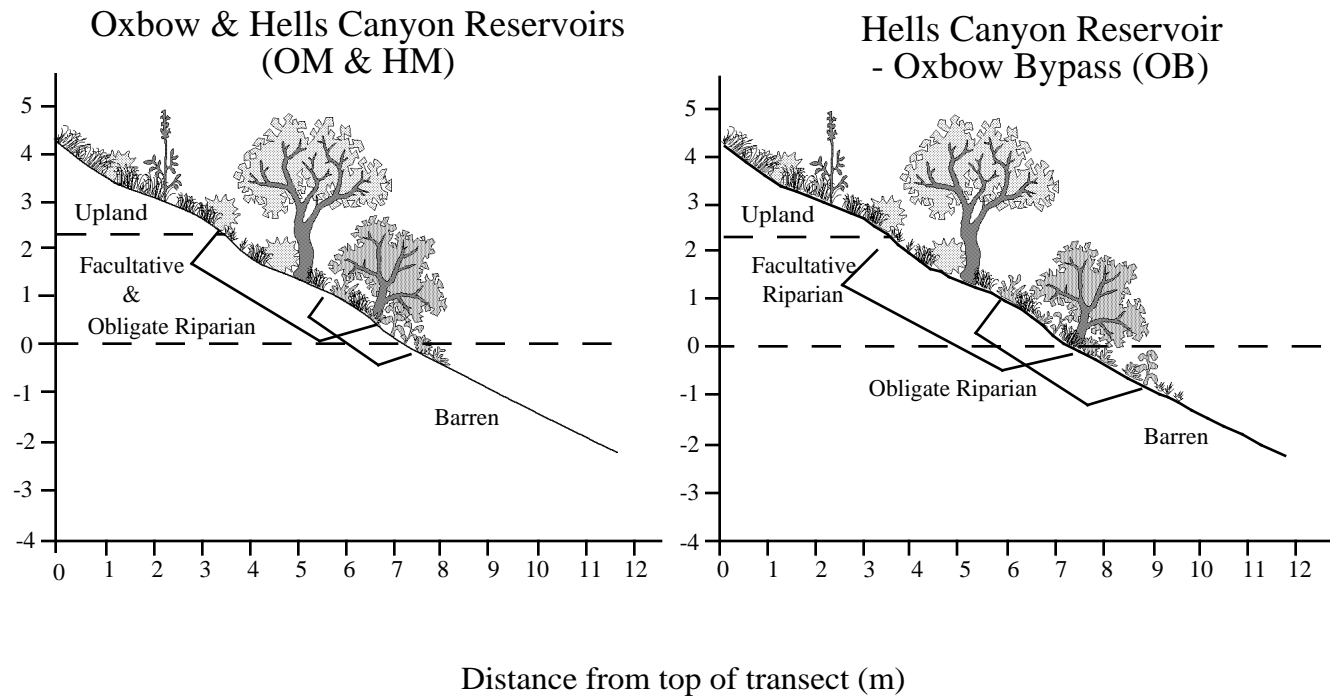


Figure 2.28. Elevational distribution of shoreline vegetation along the Brownlee Reservoir - Headwater (BH) from 1998 to 2000 (species in each category are listed in Appendix 2.1.).

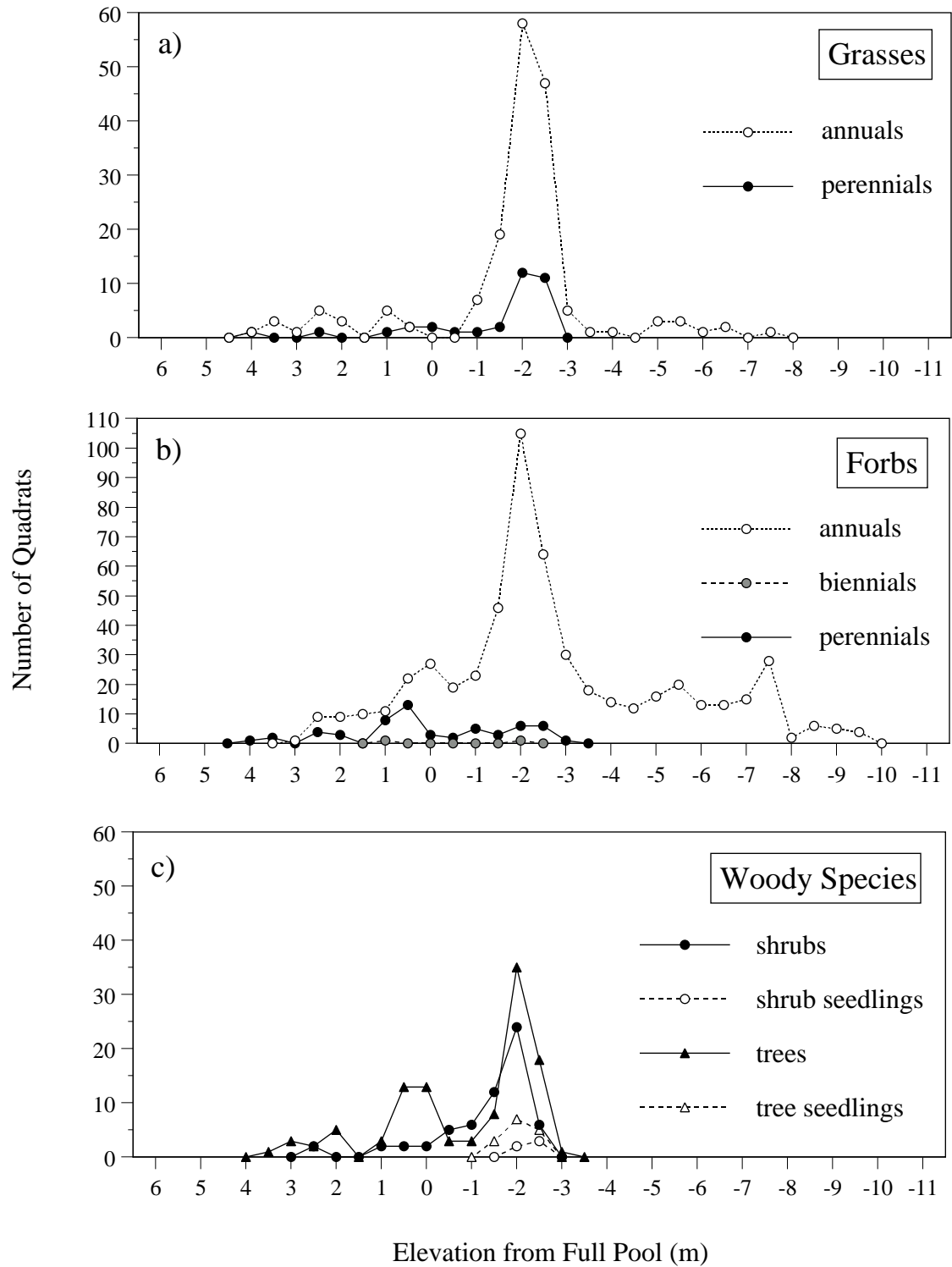


Figure 2.29. Canonical correspondence analysis (CCA) ordination of sample plots for Brownlee Reservoir - Headwater (BH). Each point represents one quadrat. Abbreviations are defined in Table 2.9.

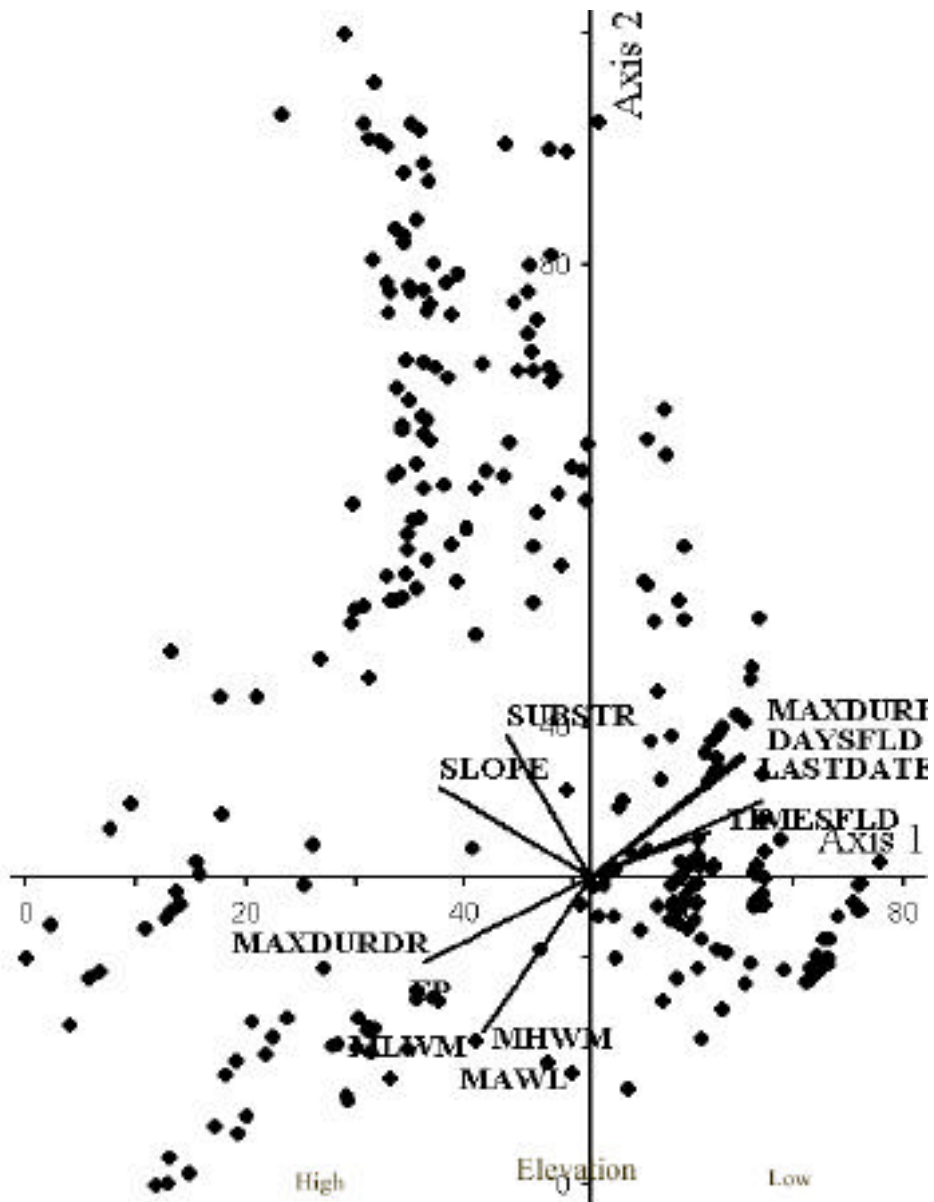


Figure 2.30. Canonical correspondence analysis (CCA) ordination of plant species for Brownlee Reservoir - Headwater (BH). Abbreviations of species are defined in Appendix 2.1.

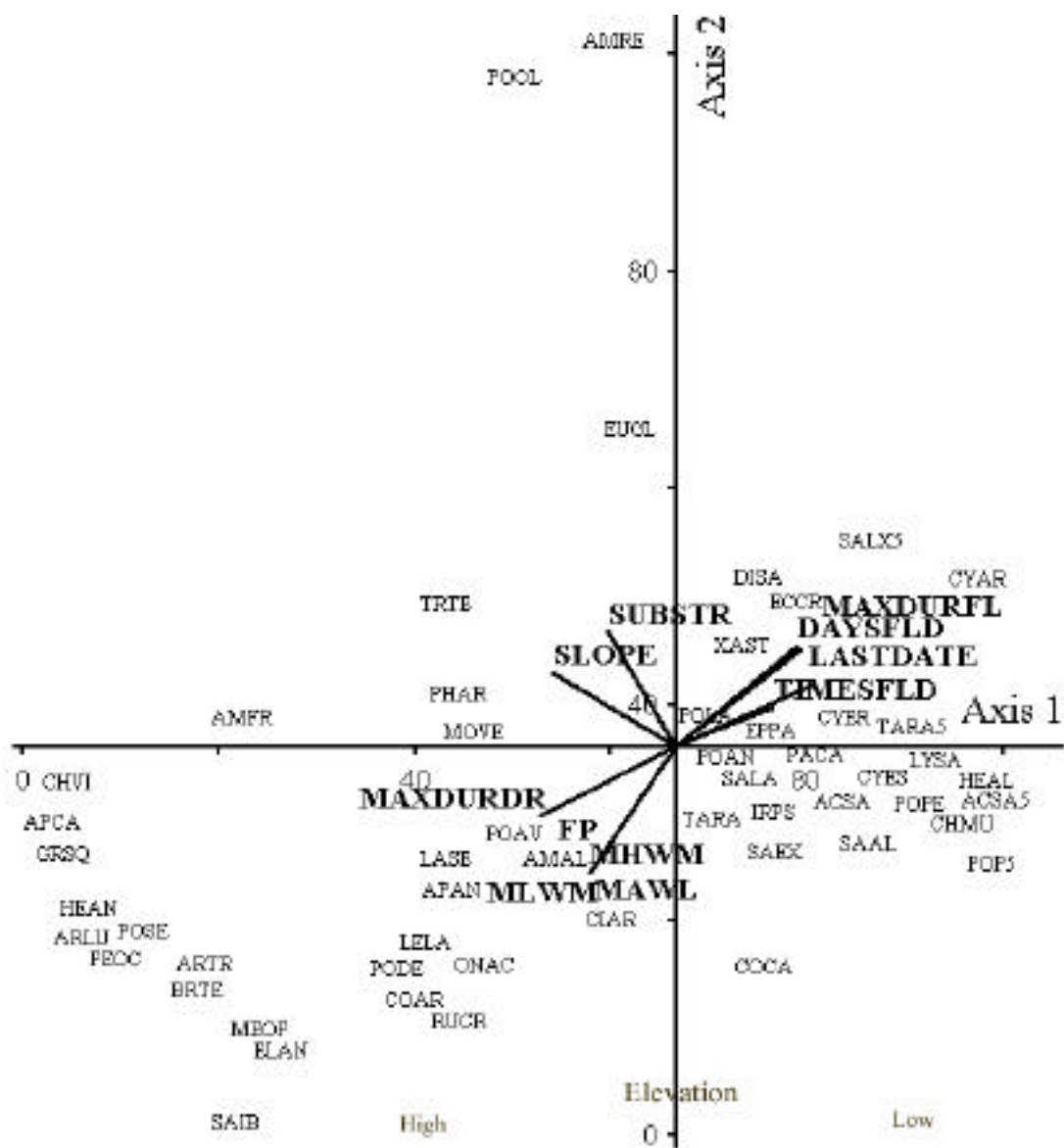


Figure 2.31. Schematic of vertical zonation of vegetation types for the shorelines along Brownlee Reservoir - Headwater reach.

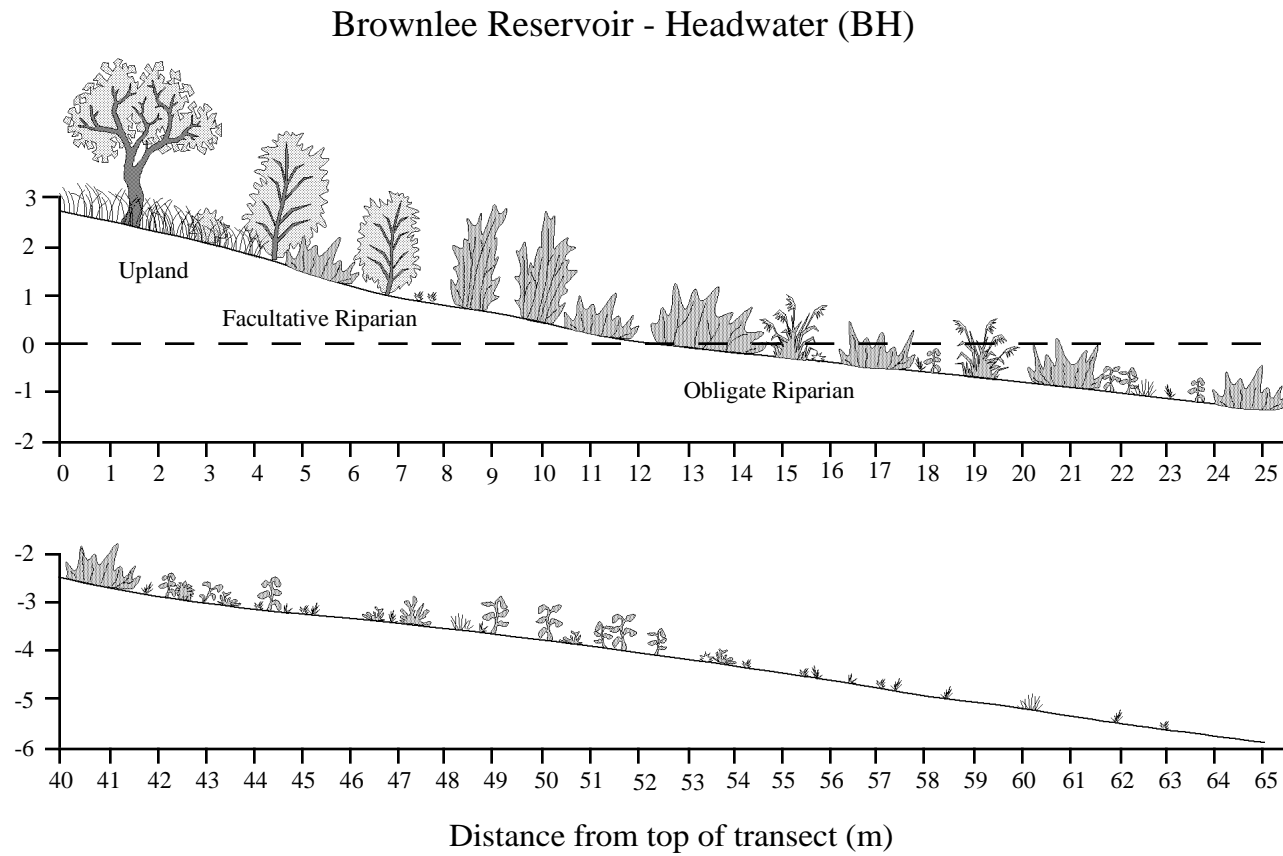


Figure 2.32. Elevational distribution of shoreline vegetation along the Brownlee Reservoir - Powder River Arm (BP) from 1998 to 2000 (species in each category are listed in Appendix 2.1.).

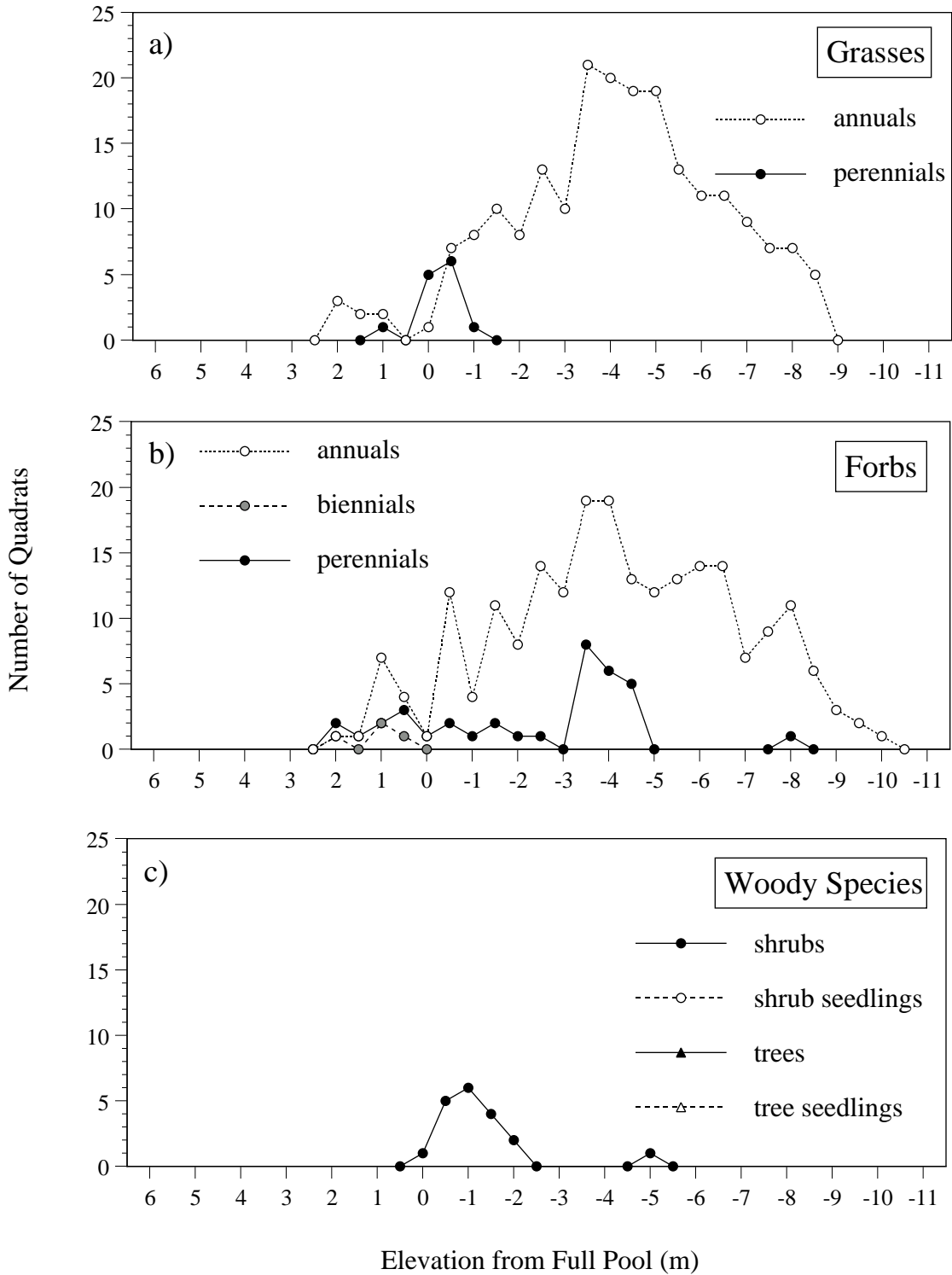


Figure 2.33. Canonical correspondence analysis (CCA) ordination of sample plots for Brownlee Reservoir - Powder River Arm (BP). Each point represents one quadrat. Abbreviations are defined in Table 2.9.

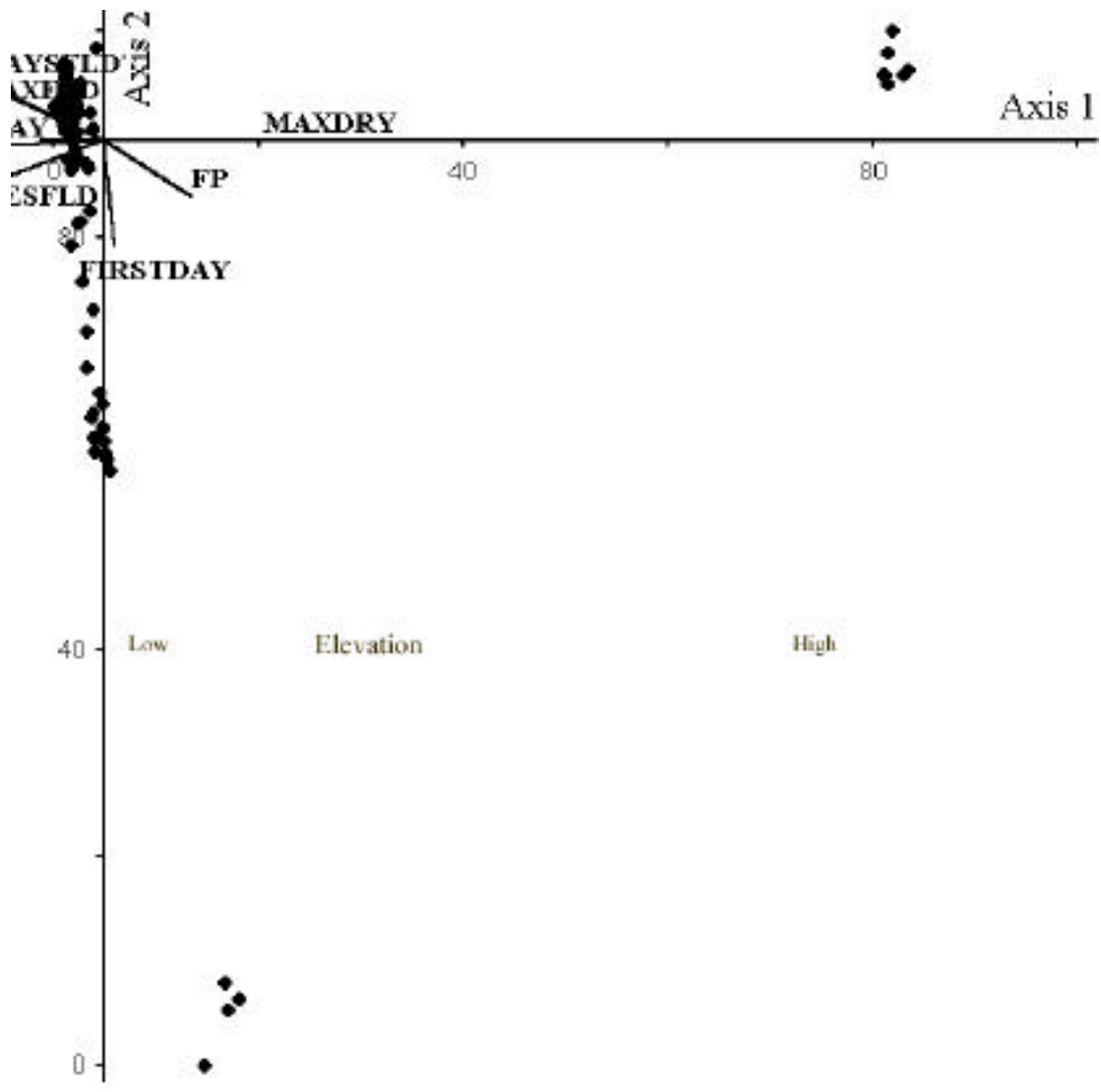


Figure 2.34. Canonical correspondence analysis (CCA) ordination of plant species for Brownlee Reservoir - Powder River Arm (BP). Abbreviations of species are defined in Appendix 2.1.

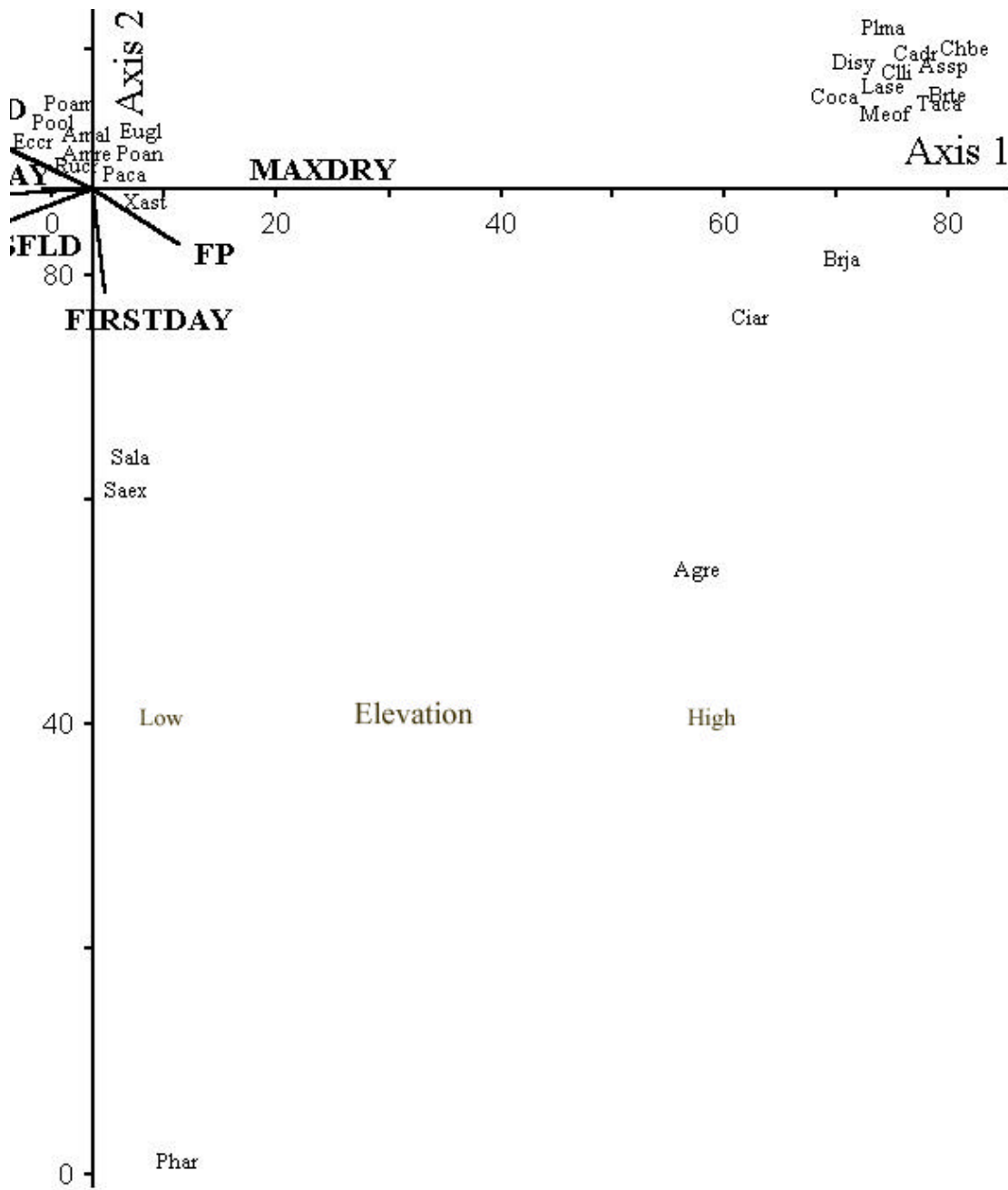


Figure 2.35. Schematic of vertical zonation of vegetation types for the shorelines along Brownlee Reservoir - Powder River Arm.

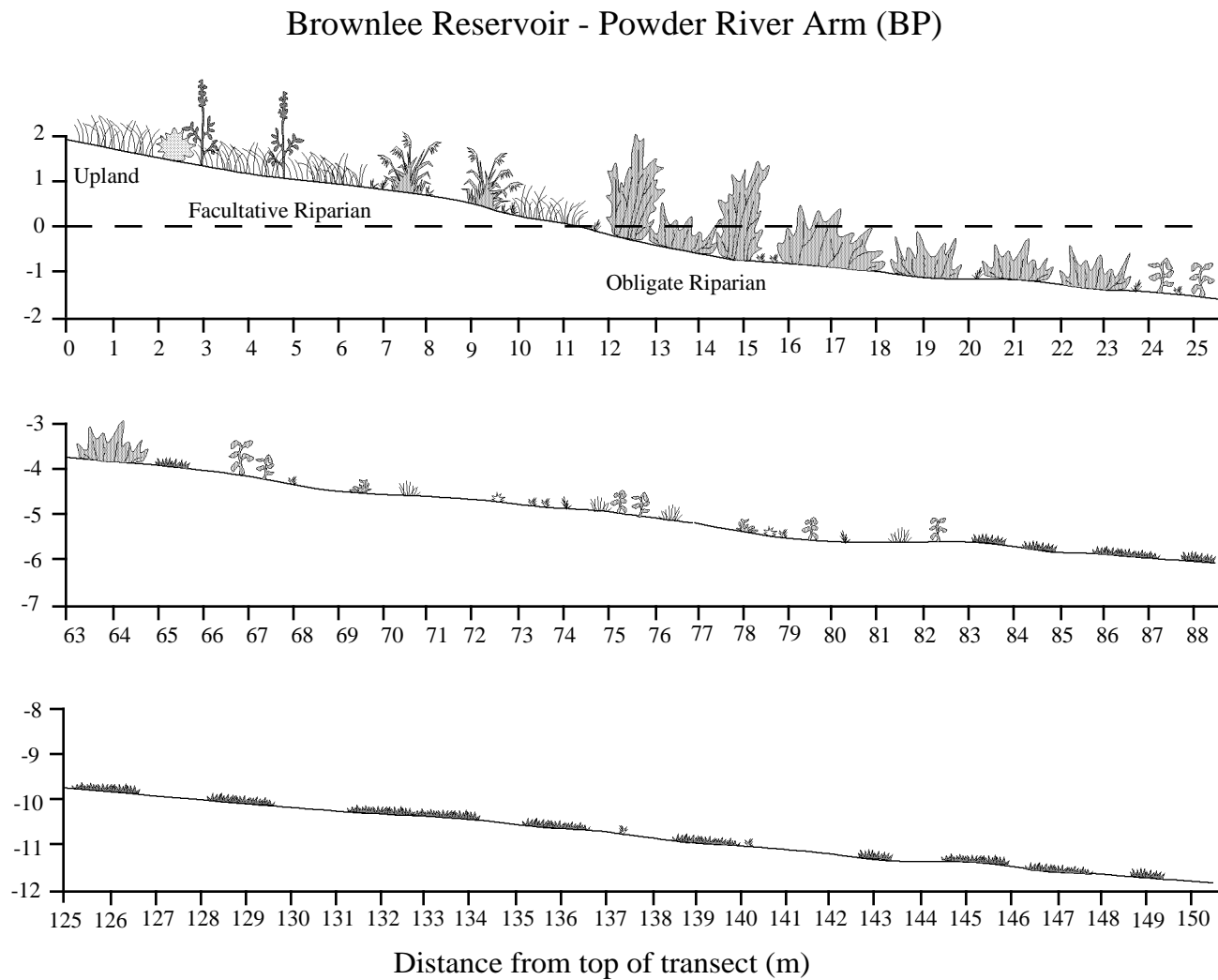


Figure 2.36. Elevational distribution of shoreline vegetation along the Hells Canyon Reservoir - Oxbow Bypass (OB) from 1998 to 2000 (species in each category are listed in Appendix 2.1.).

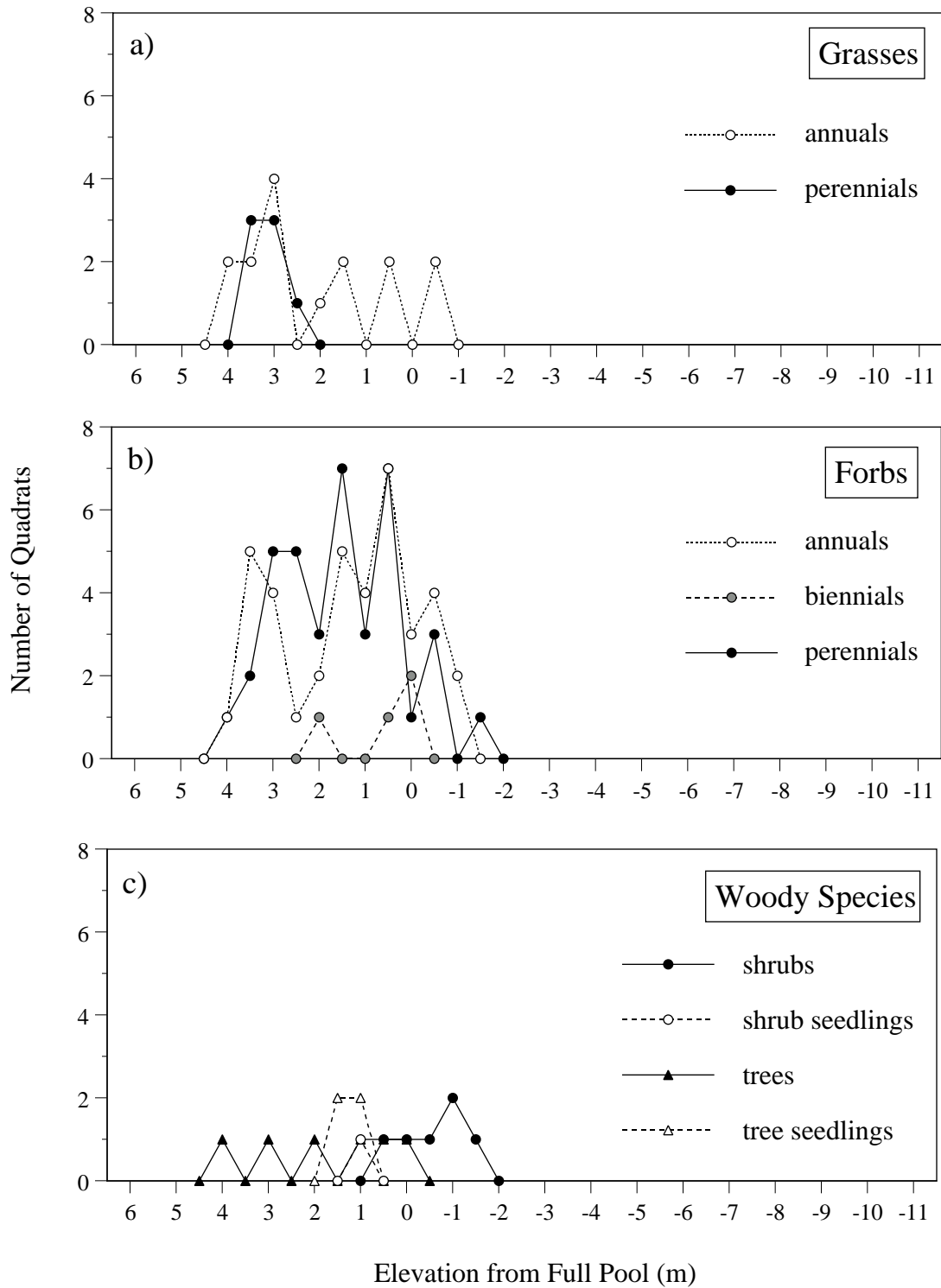


Figure 2.37. Canonical correspondence analysis (CCA) ordination of sample plots for Hells Canyon Reservoir - Oxbow Bypass (OB). Each point represents one quadrat. Abbreviations are defined in Table 2.9.

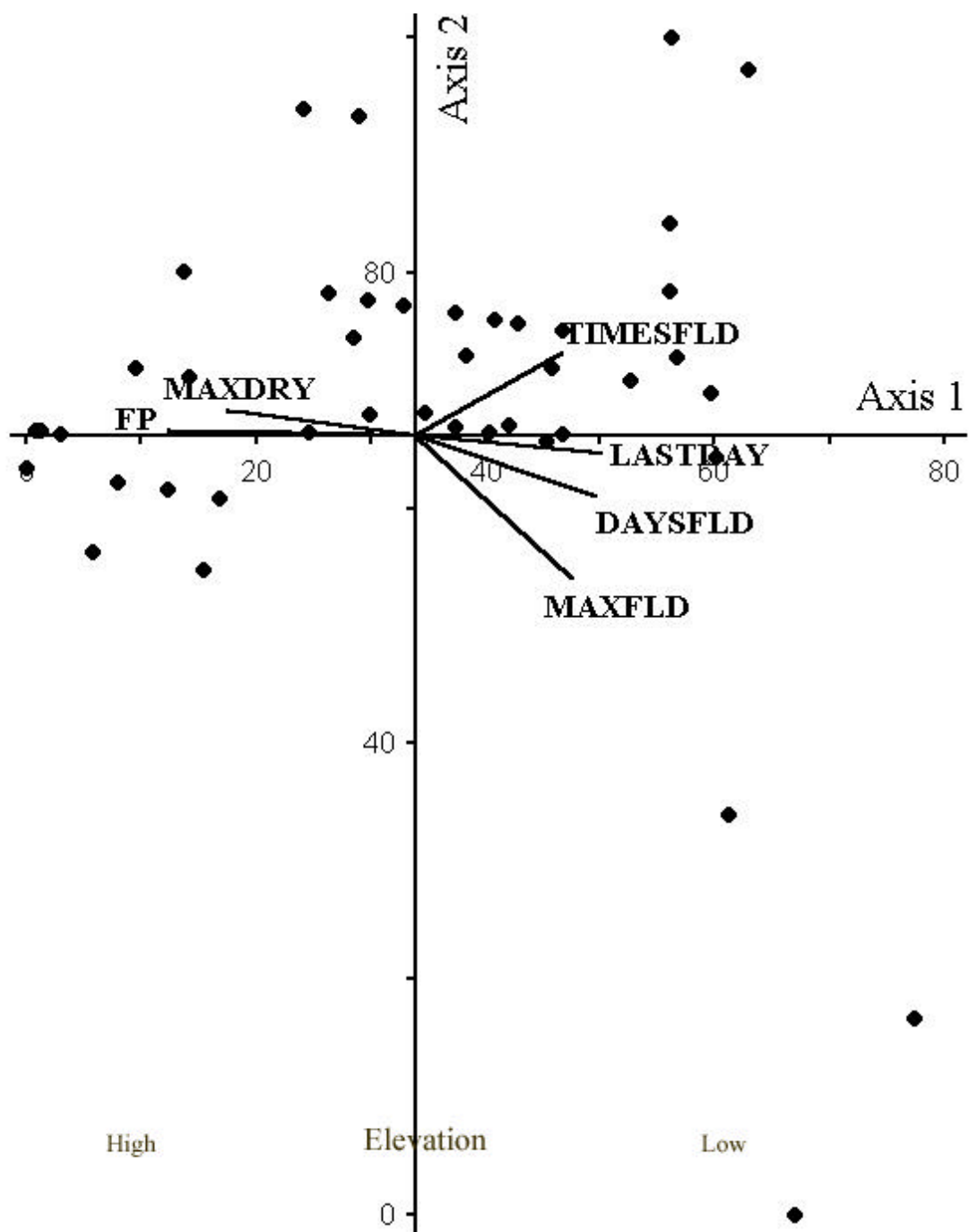


Figure 2.38. Canonical correspondence analysis (CCA) ordination of plant species for Hells Canyon Reservoir - Oxbow Bypass (OB). Abbreviations of species are defined in Appendix 2.1.

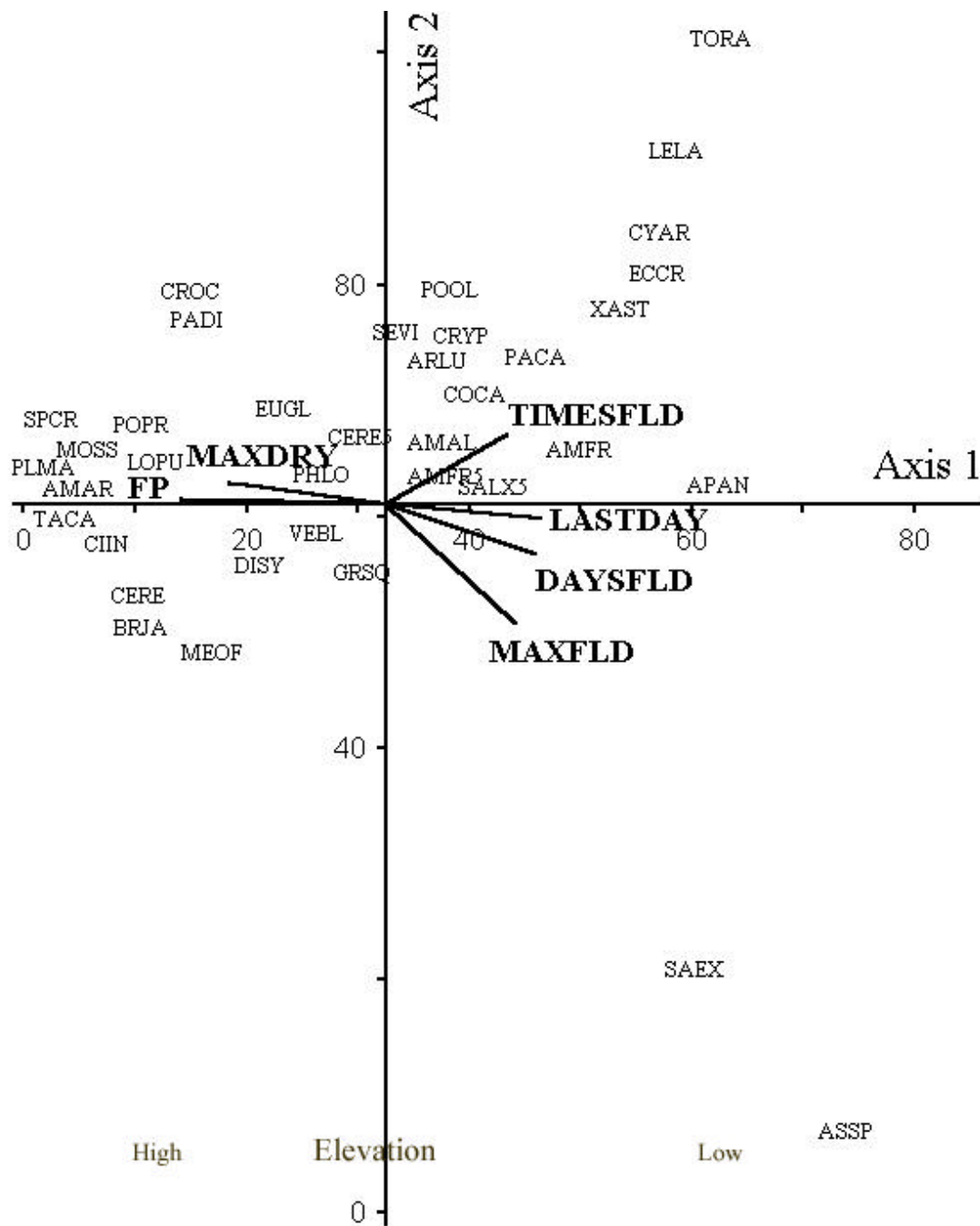


Figure 2.39. Annual variation in flow (maximum, average, and minimum daily) at the Weiser Gage and Hells Canyon Dam from 1968 to 1999.

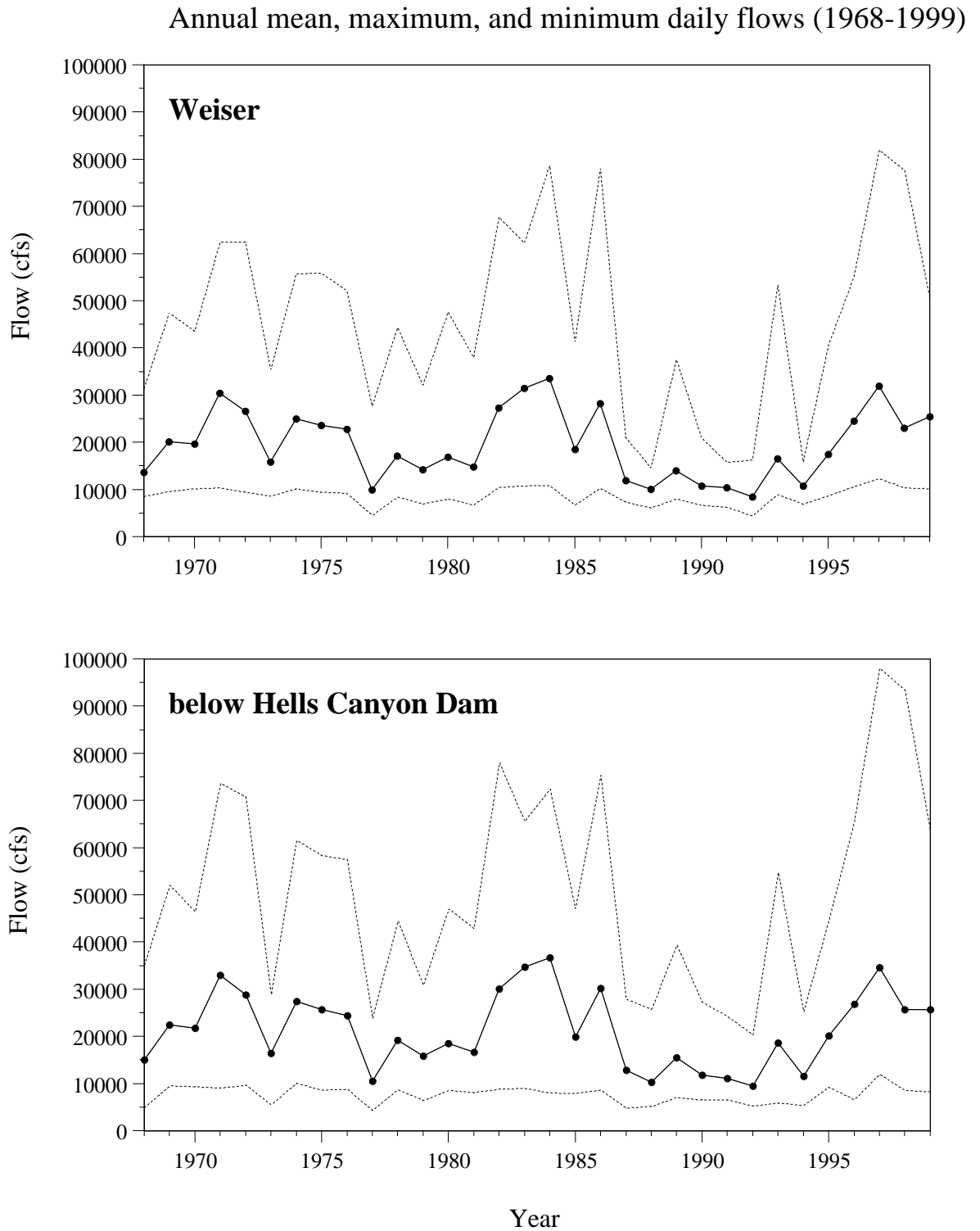


Figure 2.40. Annual variation in flow (maximum, average, and minimum daily) at the Weiser Gage and Hells Canyon Dam from 1968 to 1999.

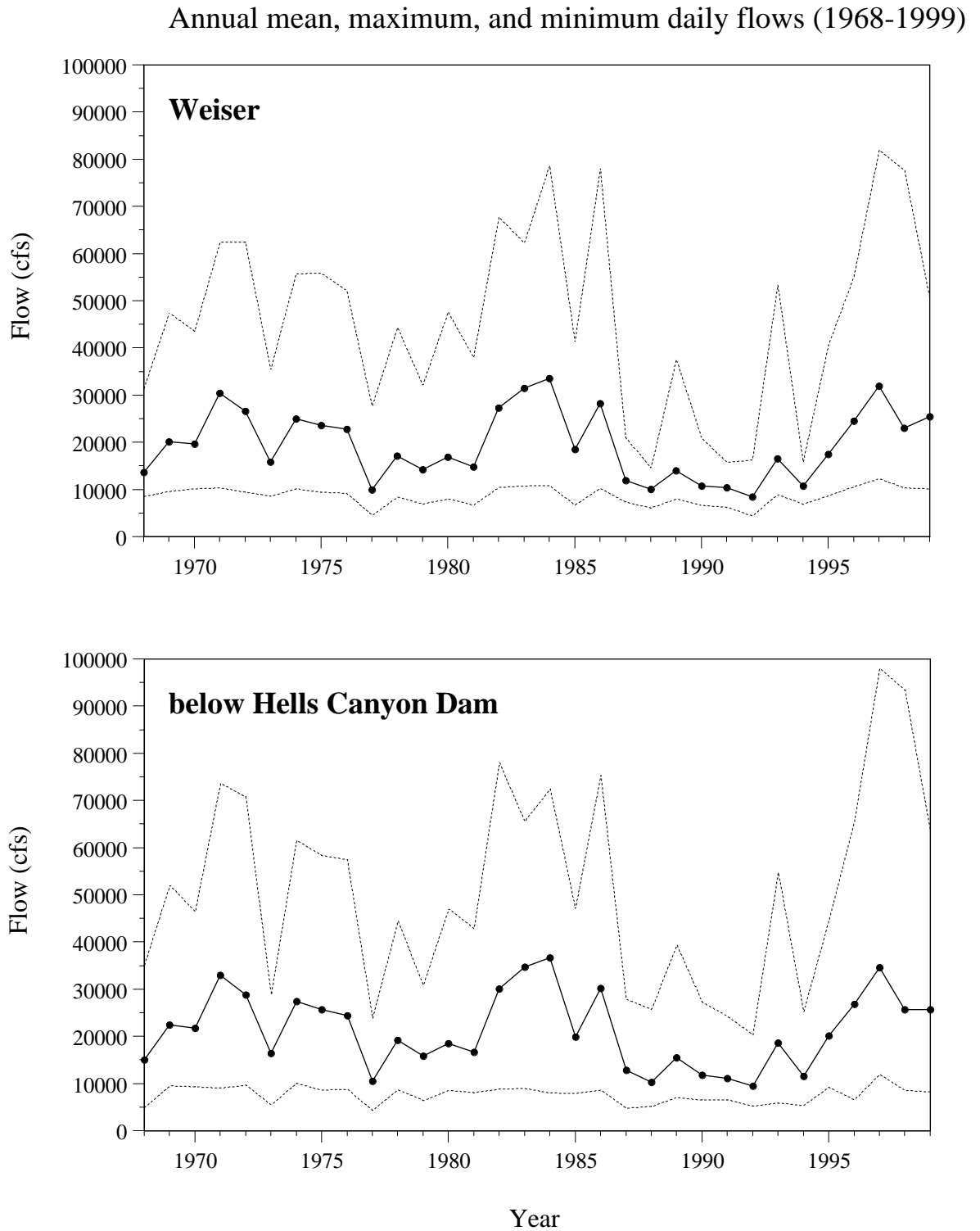


Figure 2.41. Elevational distribution of vegetation along the Weiser Reach (WR) from 1998 to 2000 (species in each category are listed in Appendix 2.1.).

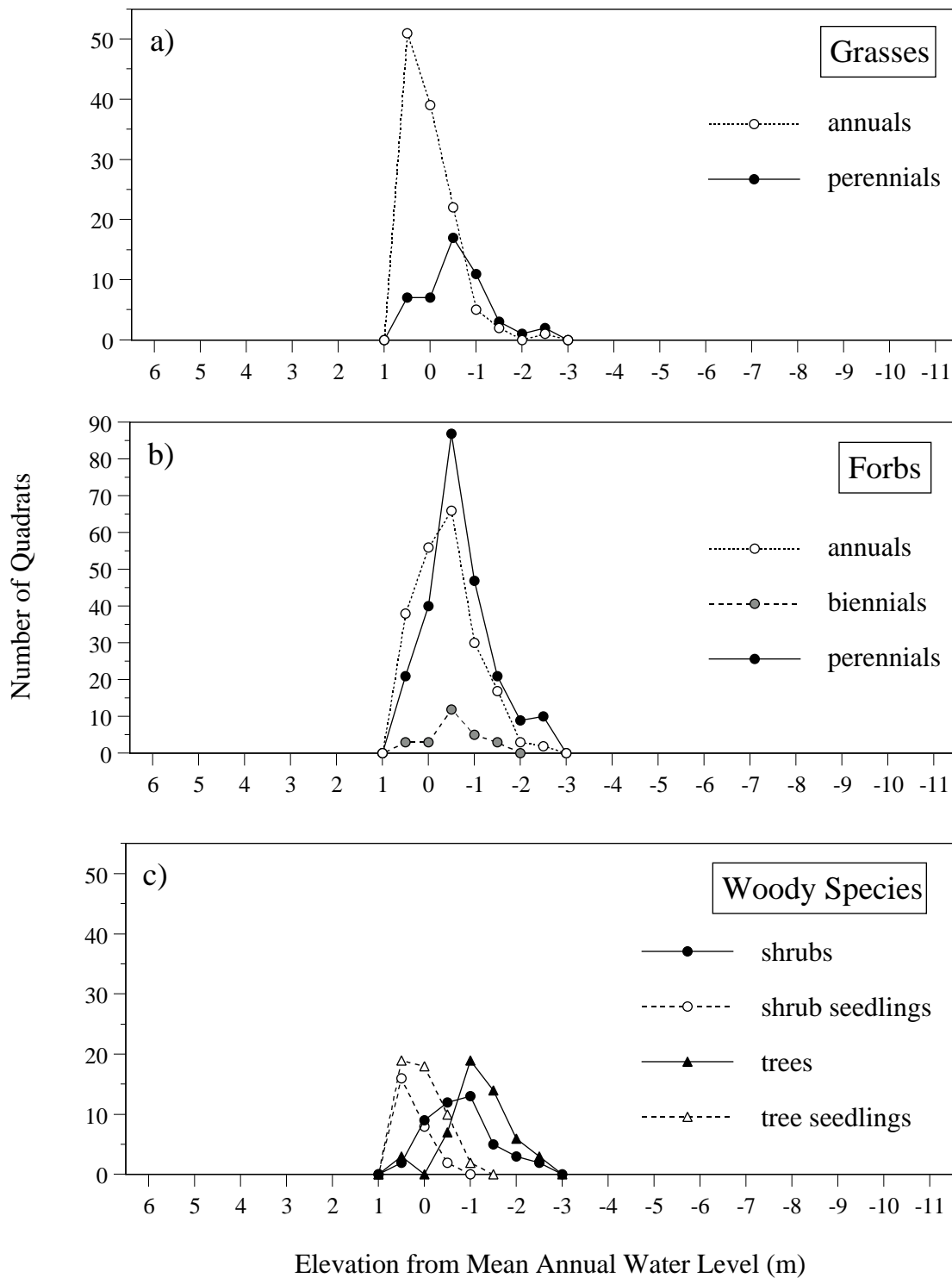


Figure 2.42. Average cover indices for shoreline vegetation along the Weiser Reach (WR) (species in each category are listed in Appendix 2.1.).

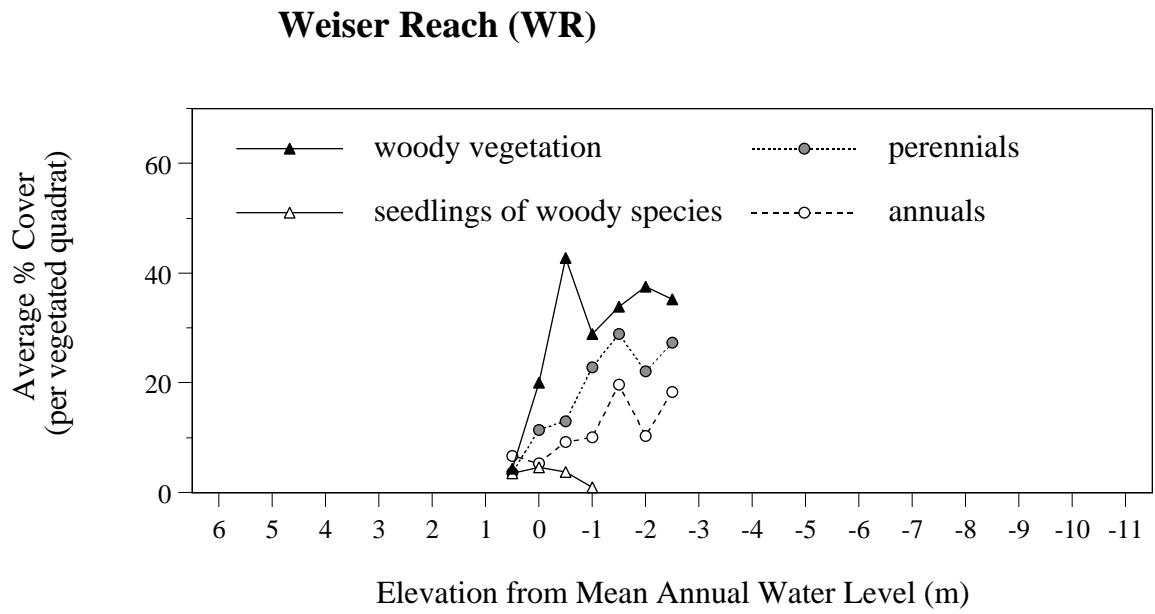


Figure 2.43. Relative cover indices for shoreline vegetation along the Weiser Reach (WR) (species in each category are listed in Appendix 2.1.).

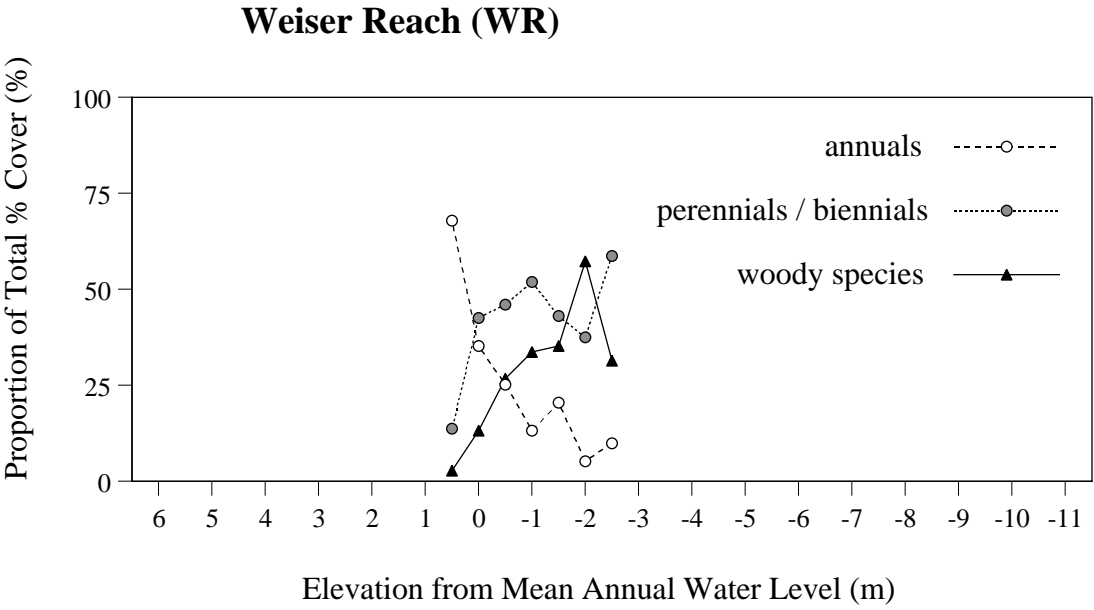
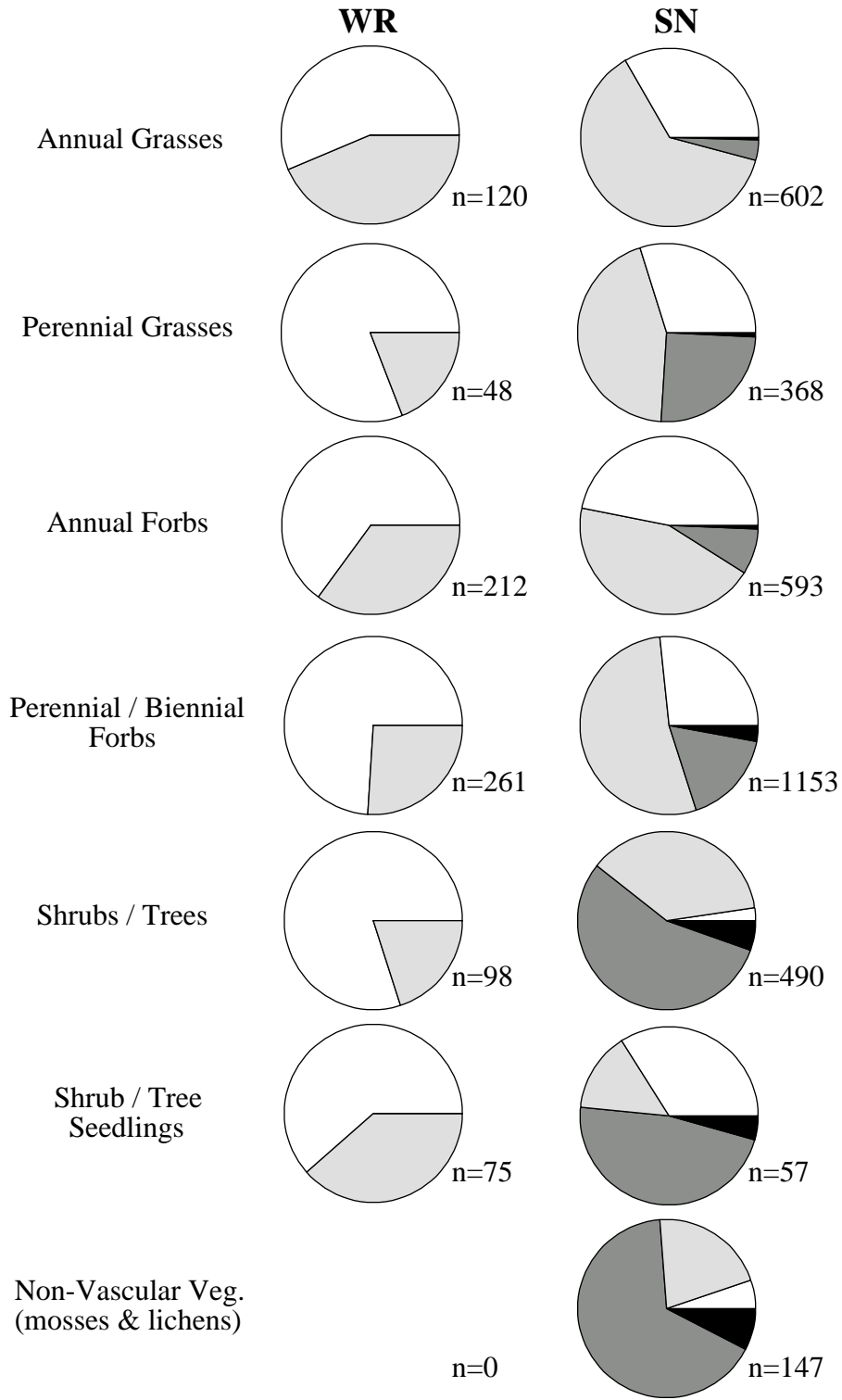


Figure 2.44 Substrate affinities of shoreline vegetation along the Weiser Reach (WR) and Snake River Reach (SN). The number of quadrats in each sample is indicated (species in each category are listed in Appendix 2.1.).



Substrates: Boulder/Bedrock Coarse Fine/Coarse Fine

Figure 2.45. Habitat affinities of shoreline vegetation along the Weiser Reach (WR) and Snake River Reach (SN). The number of quadrats in each sample is indicated (species in each category are listed in Appendix 2.1.).

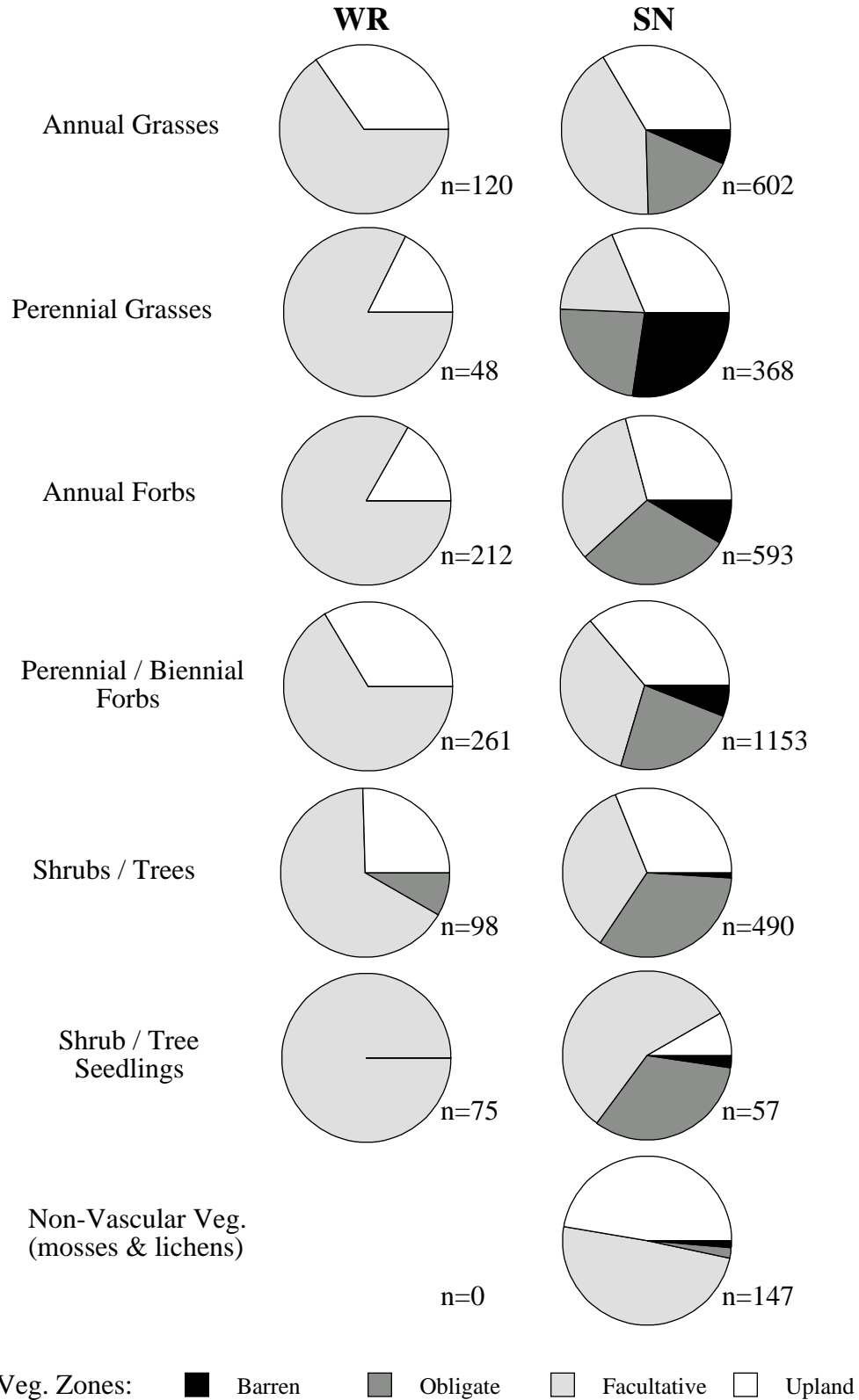


Figure 2.46. Canonical correspondence analysis (CCA) ordination of plant species for Weiser Reach (WR). Abbreviations of species are defined in Appendix 2.1.

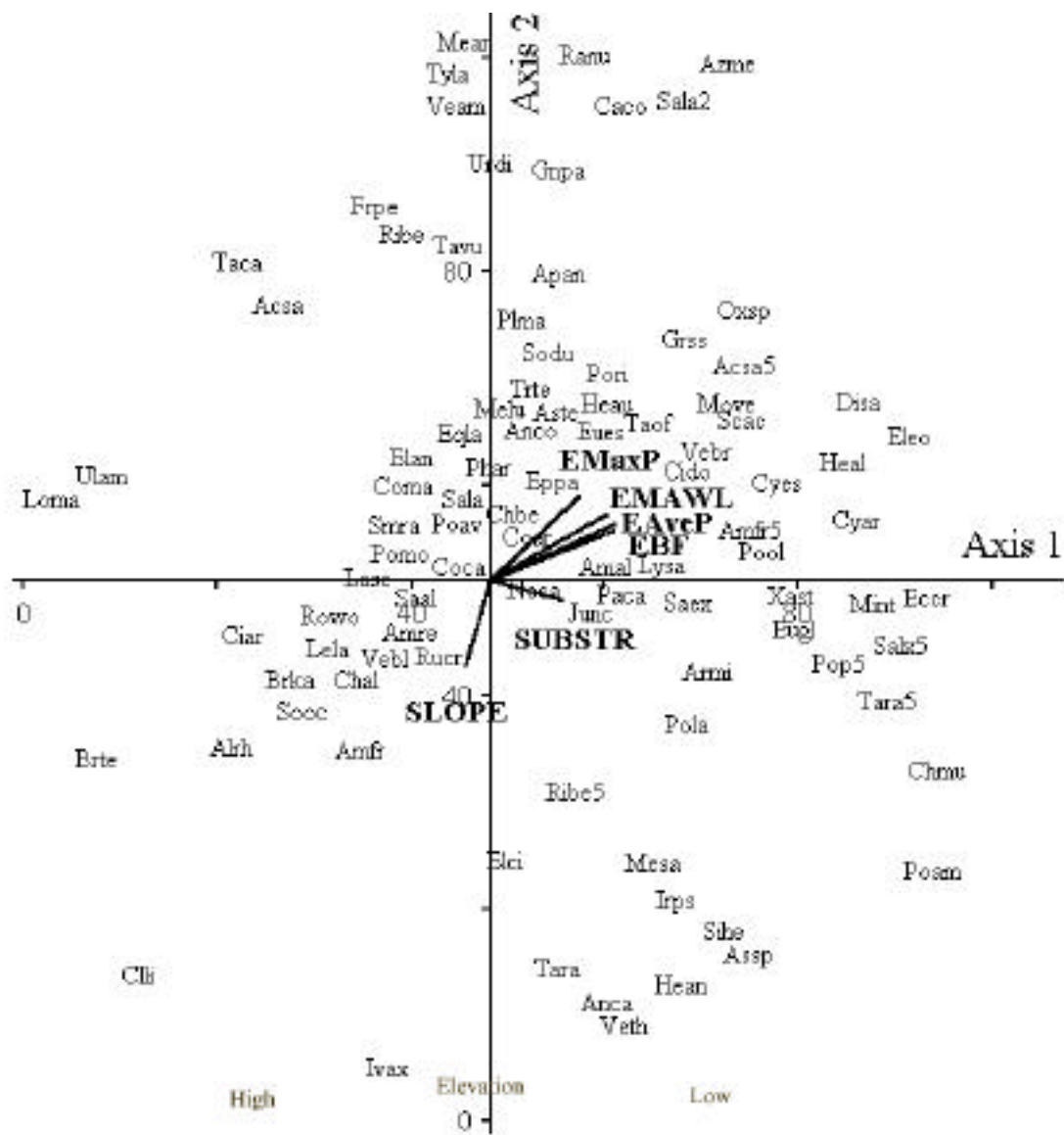


Figure 2.47. Elevational distribution of shoreline vegetation surveyed along the Snake River Reach (SN) from 1998 to 2000 (species included in each category are listed in Appendix 2.1.).

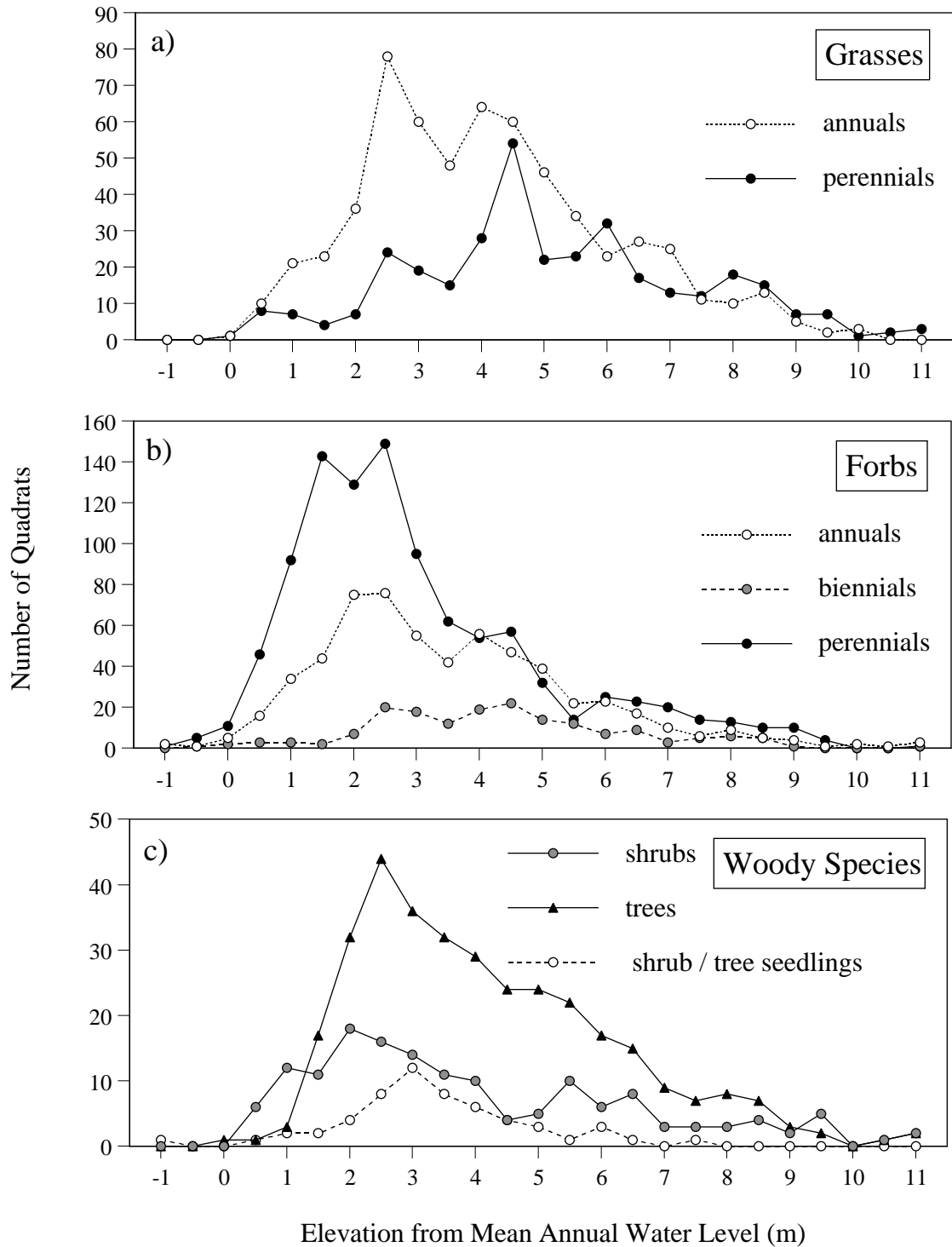


Figure 2.48. Elevational distribution of shoreline vegetation along the Snake River Reach (SN) from 1998 to 2000 (species in each category are listed in Appendix 2.1.).

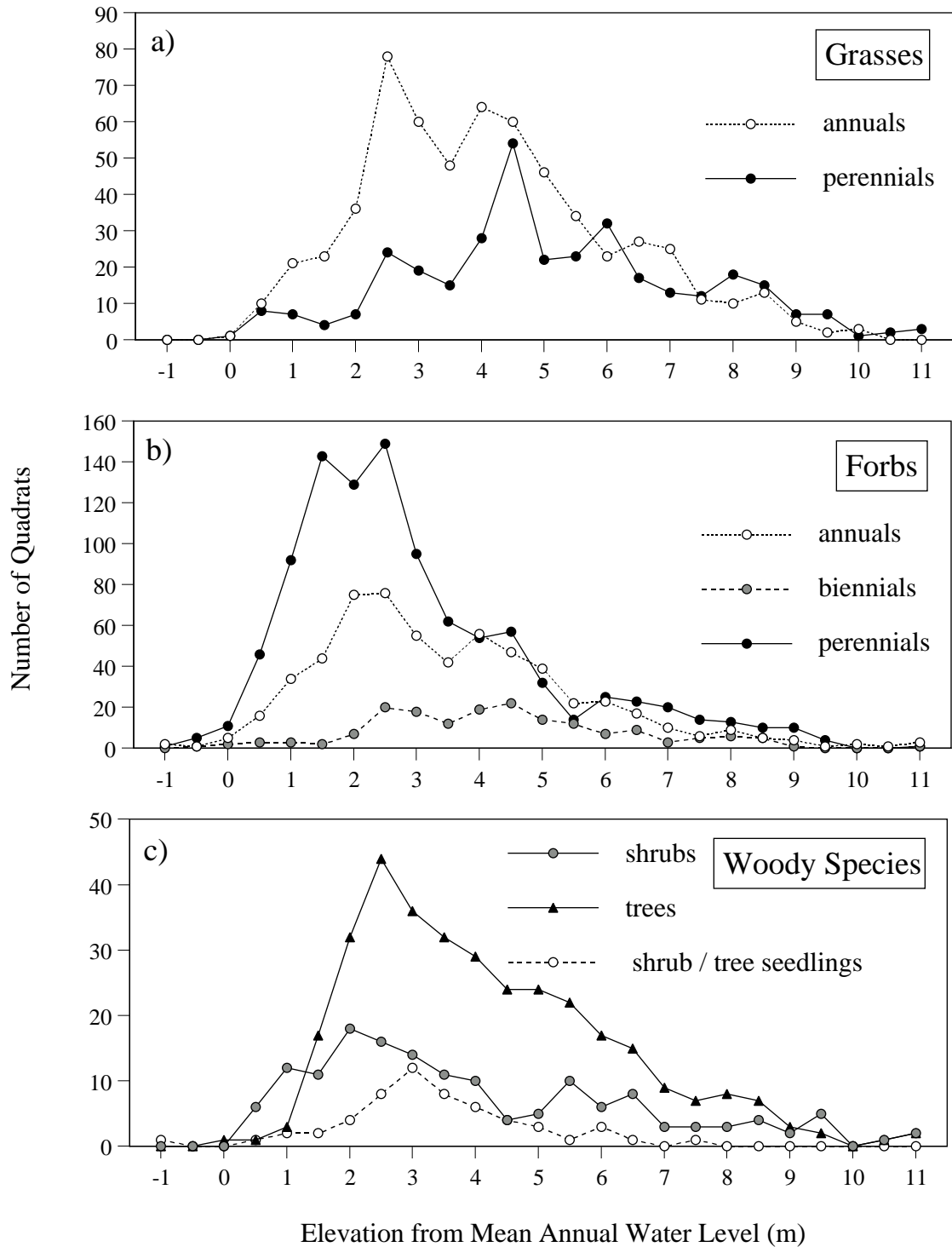


Figure 2.49. Canonical correspondence analysis (CCA) ordination of plant species for Snake River Reach (SN). Abbreviations of species are defined in Appendix 2.1.

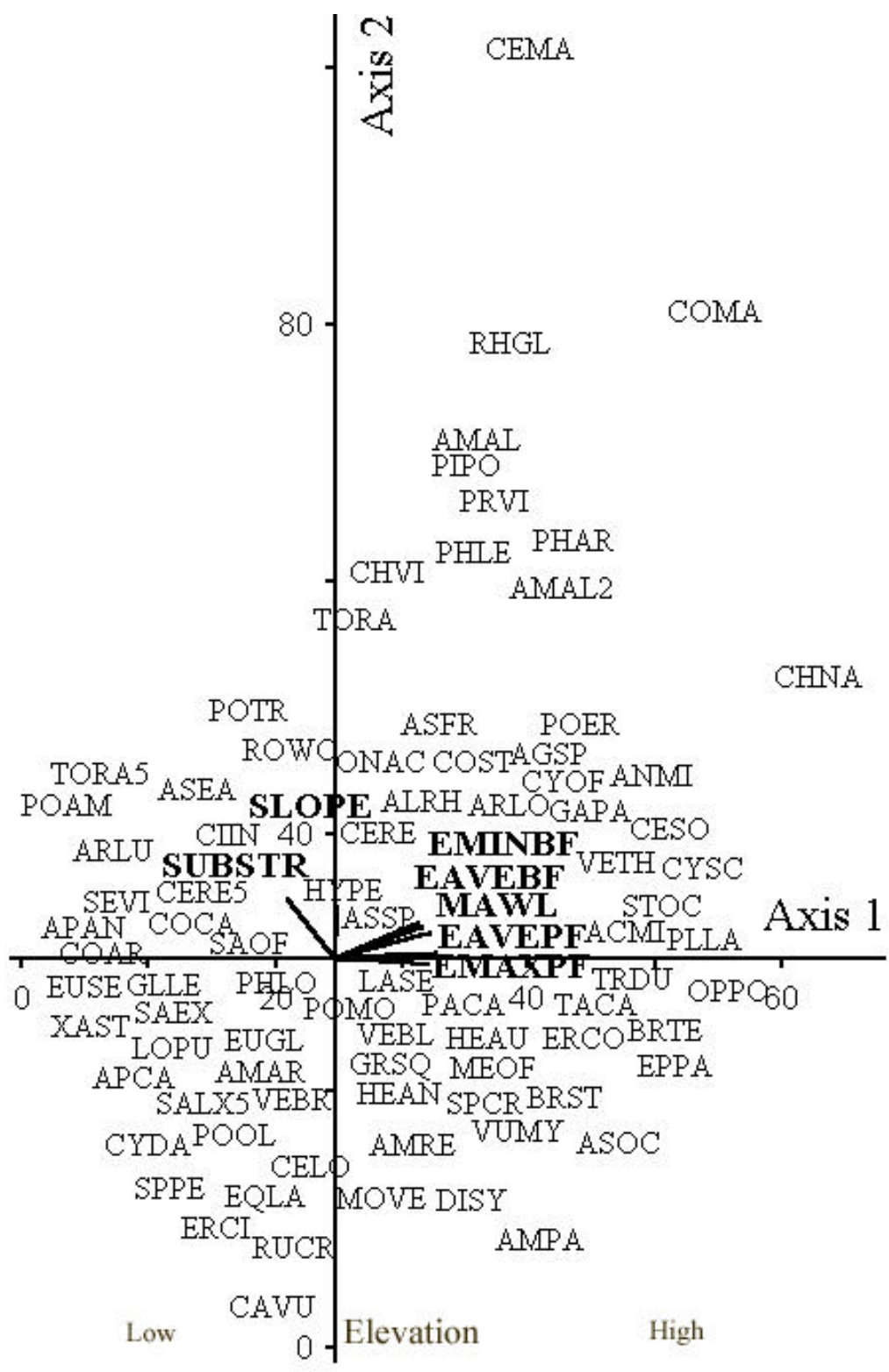


Figure 2.50. Longitudinal occurrence of species and vegetation groups along each reach of the IPC study corridor: Weiser Reach (WR), Brownlee Reservoir - Headwater (BH), - Main (BM), - Powder Arm (BP), Oxbow Reservoir - Main (OM), Hells Canyon Reservoir - Oxbow Bypass (OB), - Main (OM), Snake River Reach (SN), (species included in each category are listed in Appendix 2.1.).

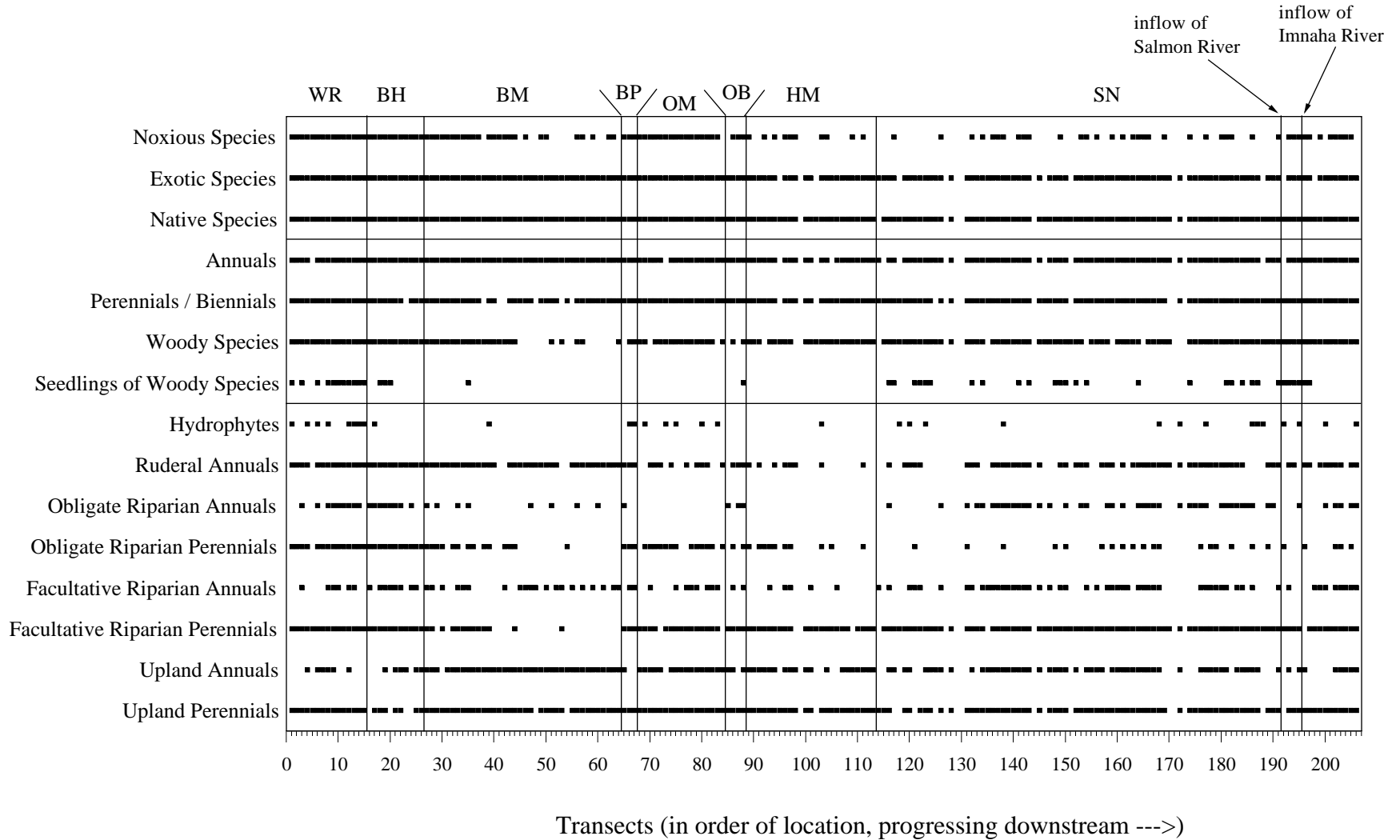


Figure 2.51. Longitudinal occurrence of species and vegetation groups along each reach of the IPC study corridor. (Weiser Reach (WR), Brownlee Reservoir - Headwater (BH), - Main (BM), - Powder Arm (BP), Oxbow Reservoir - Main (OM), Hells Canyon Reservoir - Oxbow Bypass (OB), - Main (OM), Snake River Reach (SN)) (species in each category are listed in Appendix 2.1.).

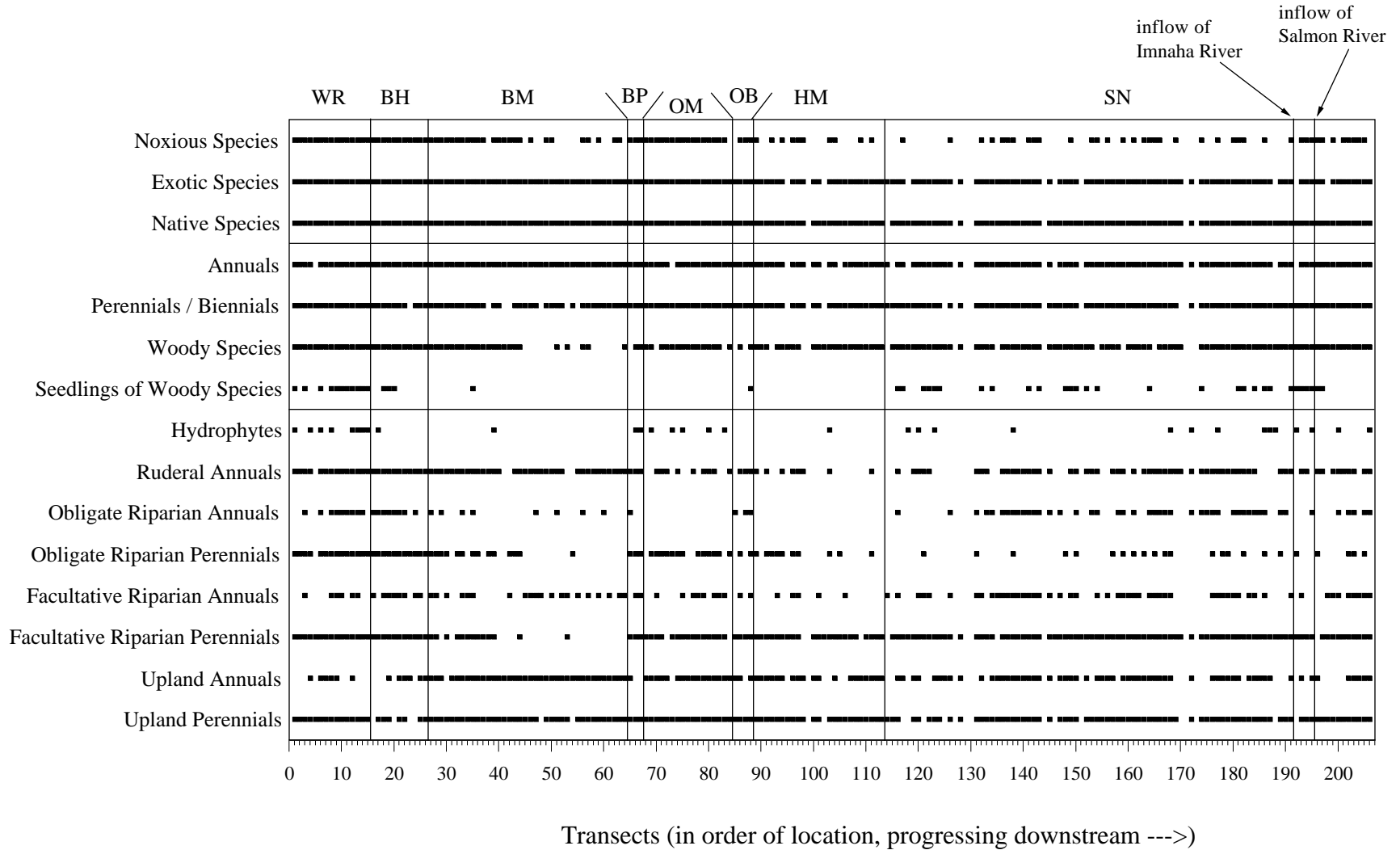


Figure 2.52. Proportion of quadrats occupied by woody and herbaceous species along each reach.

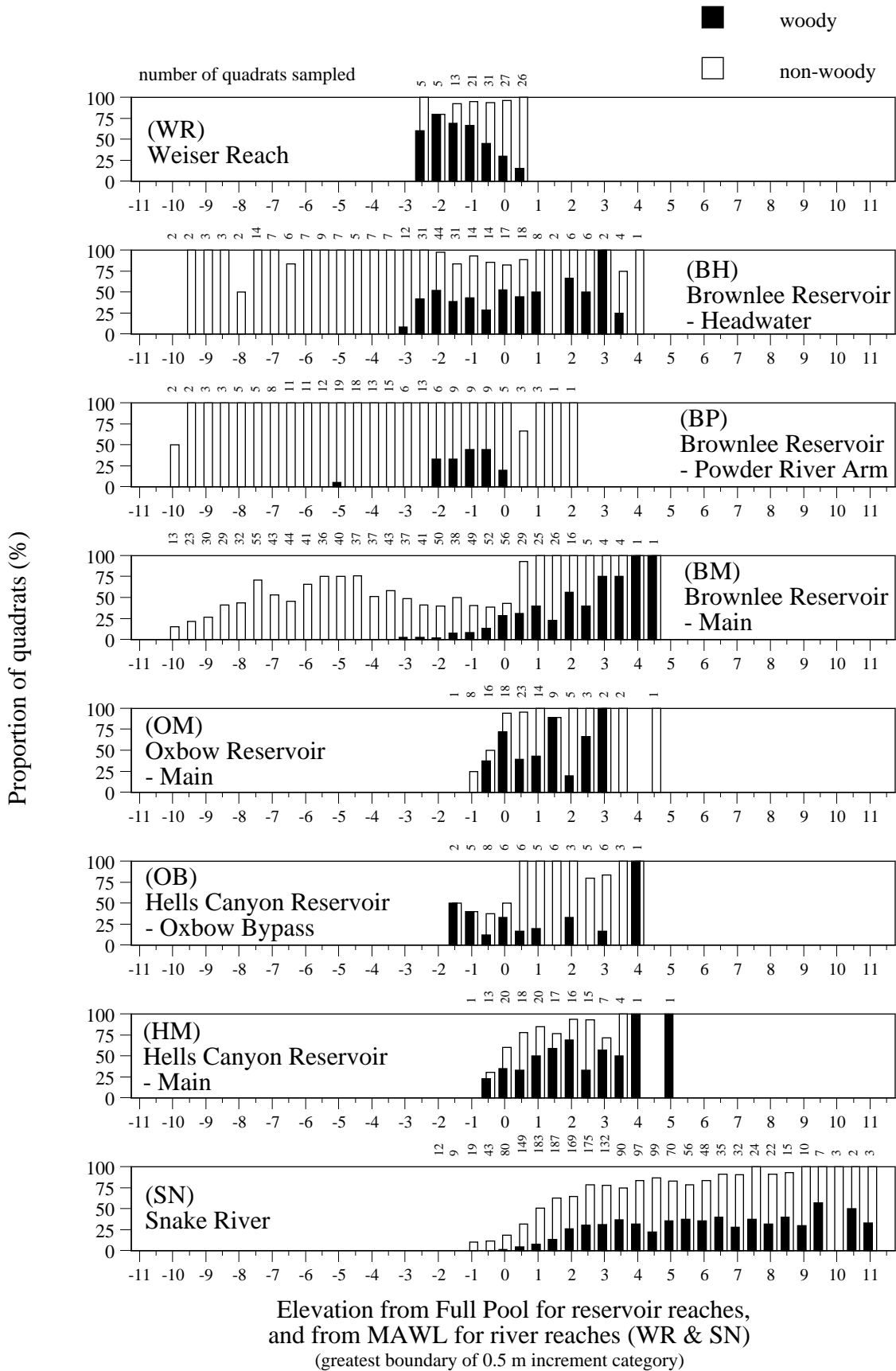


Figure 2.53. Proportion of quadrats occupied by native and exotic herbaceous (non-woody) species along each reach.

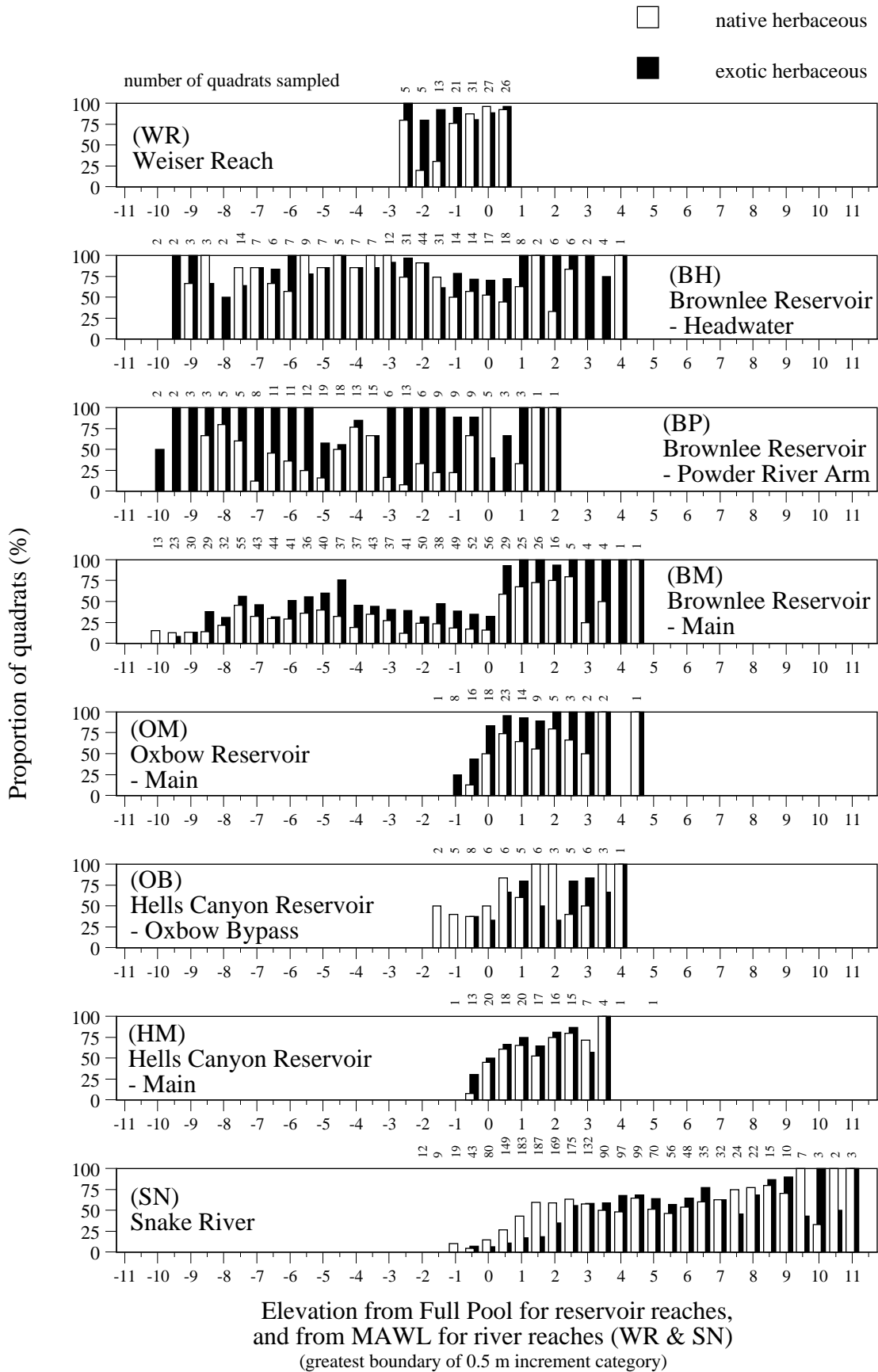
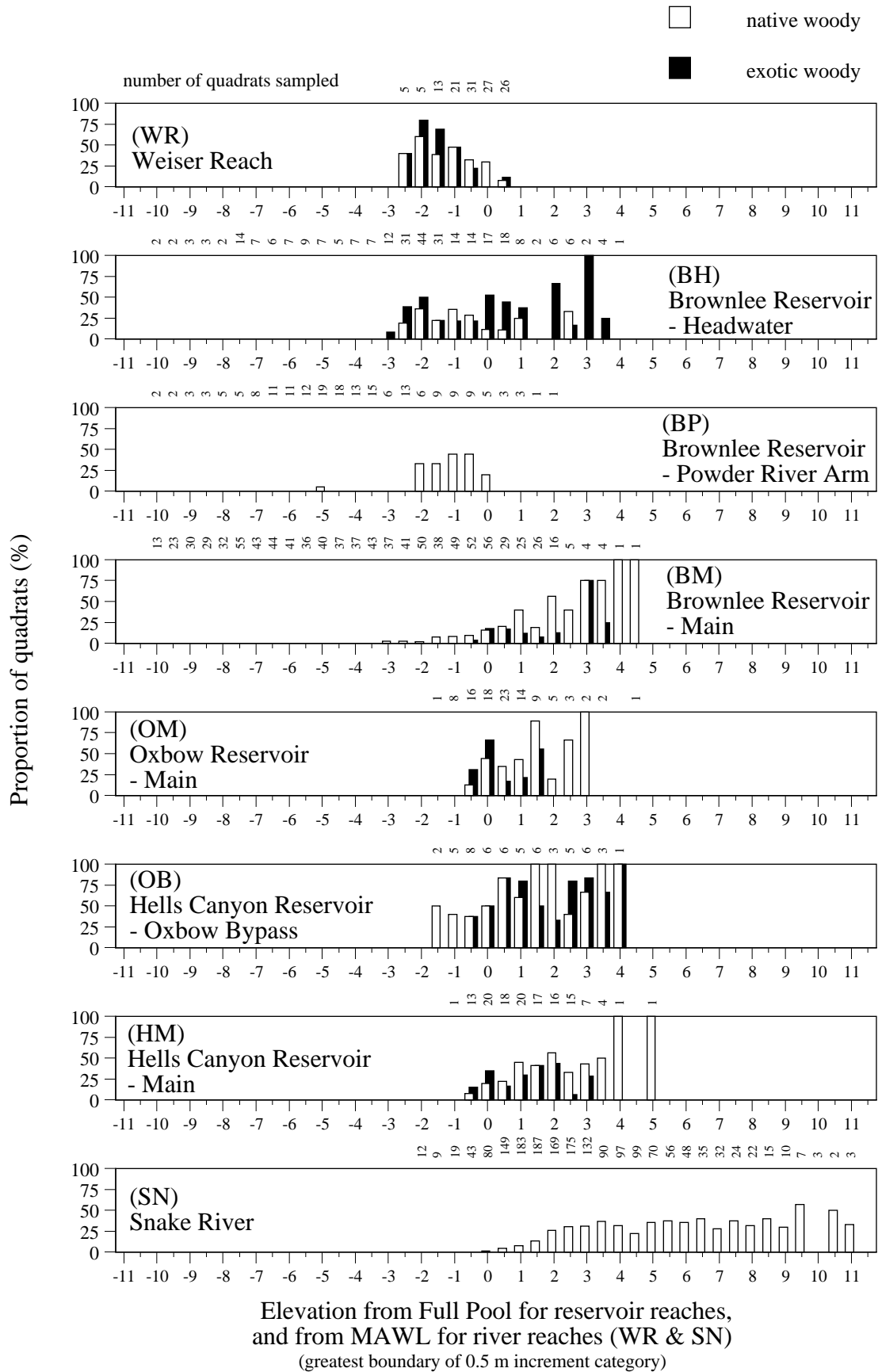


Figure 2.54. Proportion of quadrats occupied by woody native and exotic species along each reach.



Appendix 2.1. Prevalence (% of quadrats where present per reach) of species present along two or more study reaches (Weiser Reach (WR), Brownlee Reservoir–Headwater (BH), –Main (BM), – Powder River Arm (BP), Oxbow Reservoir–Main (OM), Hells Canyon Reservoir –Oxbow Bypass (OB), –Main (HM), and Snake River Reach (SN)).

| Life-form | Code | Species | WR | BH | BM | BP | OM | HB | HM | SN |
|-------------------|----------------------------|-----------------------------------|------|------|------|------|------|------|------|------|
| Annual Grasses | BRJA | <i>Bromus japonicus</i> | | | 2.7 | 2.1 | 21.6 | 5.4 | 15.8 | |
| | BRST | <i>Bromus sterilis</i> | | | 0.9 | | 5.9 | | 8.3 | 6.3 |
| | BRTE | <i>Bromus tectorum</i> | 1.6 | 5.8 | 10.4 | 1.0 | 32.4 | 1.8 | 35.3 | 11.9 |
| | DISA | <i>Digitaria sanguinalis</i> | 4.7 | 0.7 | 0.1 | | | | | |
| | ECCR | <i>Echinochola crus-galli</i> | 8.6 | 12.7 | 2.5 | 15.6 | | 3.6 | | 0.1 |
| | FEOC | <i>Festuca octoflora</i> | | 0.3 | | | | | 3.0 | |
| | HEAL | <i>Heleochloa alopecuroides</i> | 28.9 | 13.1 | | | | | | |
| | PACA | <i>Panicum capillare</i> | 10.9 | 11.3 | | 16.1 | | 3.6 | | 10.8 |
| | POAN | <i>Poa annua</i> | | 10.0 | 1.4 | 49.5 | | 1.8 | | |
| | TACA | <i>Taeniatherum caput-medusae</i> | 0.8 | | 3.7 | 1.0 | 22.5 | 5.4 | 6.0 | 0.1 |
| Annual Forbs | AMAL | <i>Amaranthus albus</i> | 5.5 | 22.0 | 18.5 | 10.9 | 2.9 | 3.6 | 1.5 | 0.5 |
| | AMAR | <i>Ambrosia artemisiifolia</i> | | | 0.1 | | 2.0 | 1.8 | 1.5 | 1.0 |
| | AMPA | <i>Amaranthus palmeri</i> | | | 0.2 | | | | 2.3 | 0.7 |
| | AMRE | <i>Amaranthus retroflexus</i> | 0.8 | 18.6 | 5.2 | 8.3 | | | | 0.3 |
| | CHBE | <i>Chenopodium berlandieri</i> | 18.8 | | | 2.1 | | | | |
| | CHMU | <i>Chenopodium murale</i> | 11.7 | 9.6 | | | | | | |
| | COCA | <i>Conyza canadensis</i> | 20.3 | 2.4 | 0.3 | 2.1 | 2.0 | 3.6 | | 1.1 |
| | CYAR | <i>Cyperus aristatus</i> | 22.7 | 2.1 | | | | 1.8 | | |
| | CYER | <i>Cyperus erthyrorhizos</i> | | 0.7 | | | 2.0 | | | |
| | EPPA | <i>Epilobium paniculatum</i> | 0.8 | 1.4 | 1.5 | | 7.8 | | 6.8 | 0.1 |
| | EUGL | <i>Euphorbia glyptosperma</i> | 11.7 | 0.7 | 1.2 | 2.6 | | 19.6 | | 9.0 |
| | GAPA | <i>Gaura parviflora</i> | | 0.3 | 0.1 | | 1.0 | | 0.8 | 0.4 |
| | HEAN | <i>Helianthus annuus</i> | 0.8 | 0.7 | 1.7 | | 6.9 | 1.8 | 1.5 | 2.5 |
| | LASE | <i>Lactuca serriola</i> | 10.2 | 1.0 | 2.1 | 2.6 | 13.7 | | 5.3 | 1.2 |
| | MEOF | <i>Meliolotus officinalis</i> | | 1.4 | 2.6 | 0.5 | 9.8 | 1.8 | 4.5 | 10.8 |
| | MOVE | <i>Mollugo verticillata</i> | 7.8 | 4.1 | | | | | | 0.3 |
| | POAV | <i>Polygonum aviculare</i> | 3.1 | 0.7 | 0.2 | 1.6 | 2.9 | | 0.8 | |
| | POLA | <i>Polygonum lapathifolium</i> | 23.4 | 6.9 | 0.2 | | | | | |
| | POOL | <i>Portulaca oleracea</i> | 10.2 | 34.7 | 21.1 | 60.4 | | 3.6 | | 0.6 |
| | TRTE | <i>Tribulis terrestris</i> | 0.8 | 12.0 | 1.8 | | | | | 0.1 |
| XAST | <i>Xanthium strumarium</i> | 19.5 | 61.5 | 21.6 | 22.4 | | 25.0 | 0.8 | 4.0 | |
| Perennial Grasses | AGSP | <i>Agropyron spicatum</i> | | | 0.7 | | 3.9 | | 25.6 | 9.0 |
| | ELCI | <i>Elymus cinereus</i> | 7.8 | 0.3 | | | | | | |
| | PHAR | <i>Phalaris arundinacea</i> | 19.5 | 2.7 | 0.2 | 5.7 | | | 3.0 | 0.1 |
| | POBU | <i>Poa bulbosa</i> | | | 0.2 | | | | 0.8 | |
| | POPR | <i>Poa pratensis</i> | | | 0.9 | | 6.9 | 3.6 | 8.3 | |
| | POSE | <i>Poa secunda</i> | | 0.3 | 1.6 | | 2.0 | | 6.8 | |
| | SPCR | <i>Sporobolus cryptandrus</i> | | | 0.4 | | | 7.1 | 2.3 | 4.8 |

Appendix 2.1. (Cont.)

| Life-form | Code | Species | WR | BH | BM | BP | OM | HB | HM | SN |
|-----------------|------------------------------|-----------------------------------|------|-----|-----|------|------|------|-----|------|
| Perennial Forbs | ACMI | <i>Achillea millefolium</i> | | | 0.7 | | | | 1.5 | 1.3 |
| | AGUR | <i>Agastache urticifolia</i> | | | | | 3.9 | | 1.5 | |
| | APAN | <i>Apocynum androsaemifolia</i> | 7.0 | 1.7 | | | | 1.8 | | 0.8 |
| | APCA | <i>Apocynum cannabinum</i> | | 0.7 | 0.1 | | | | | 0.6 |
| | ARLU | <i>Artemesia ludoviciana</i> | | 0.3 | | | 10.8 | 19.6 | 1.5 | 8.9 |
| | ARMI | <i>Arctium minus</i> | 0.8 | | 0.3 | | | | | |
| | ASSP | <i>Asclepias speciosa</i> | 3.9 | | 0.6 | 0.5 | 5.9 | 1.8 | 3.0 | 1.0 |
| | ASTE | <i>Asteraceae species</i> | 2.3 | | | | 2.9 | | | 1.4 |
| | CADR | <i>Cardaria draba</i> | | | 0.3 | 1.6 | | | | |
| | CHVI | <i>Chrysopsis villosa hispida</i> | | 1.0 | 0.2 | | | | | 1.2 |
| | CIAR | <i>Cirsium arvense</i> | 14.8 | 0.7 | | 1.6 | | | | |
| | CIDO | <i>Cicuta douglasii</i> | 4.7 | | | | 1.0 | | 0.8 | |
| | CIIN | <i>Cichorium intybus</i> | | | | | 15.7 | 5.4 | 2.3 | 0.2 |
| | CLLI | <i>Clematis ligusticifolia</i> | 0.8 | | 0.1 | 1.0 | 6.9 | | | 0.1 |
| | COAR | <i>Convolvulus arvensis</i> | 10.9 | 1.4 | 2.7 | | 3.9 | | 3.0 | 1.2 |
| | COMA | <i>Conium maculatum</i> | 7.0 | | | | 3.9 | | 0.8 | 0.2 |
| | CYES | <i>Cyperus esculentus</i> | 10.2 | 8.2 | 0.2 | | | | | |
| | CYOF | <i>Cynoglossum officinale</i> | | | 0.4 | | 2.9 | | | 0.1 |
| | DISY | <i>Dipsacus sylvestris</i> | | | 0.1 | 2.1 | 17.6 | 1.8 | 8.3 | 1.1 |
| | ELEO | <i>Eleocharis spp.</i> | 1.6 | 0.3 | | | | | | |
| | EQLA | <i>Equisetum laevigatum</i> | 1.6 | | | | 12.7 | | | 2.5 |
| | ERCO | <i>Eriogonum compositum</i> | | | 0.3 | | 1.0 | | | 0.2 |
| | GRSQ | <i>Grindelia squarrosa</i> | | 0.7 | 0.5 | | 4.9 | 3.6 | 1.5 | 2.5 |
| | HYPE | <i>Hypericum perforatum</i> | | | | | 2.9 | | 1.5 | 4.1 |
| | IRPS | <i>Iris pseudoacorus</i> | 2.3 | 0.3 | | | 15.7 | | 0.8 | |
| | IVAX | <i>Iva axillaris</i> | 3.9 | | 0.4 | | | | | |
| | LELA | <i>Lepidium latifolium</i> | 25.8 | 6.5 | 2.0 | | 18.6 | 7.1 | 6.0 | |
| | LOMA | <i>Lomatium spp.</i> | 1.6 | | 0.5 | | | | 3.8 | 0.6 |
| | LYSA | <i>Lythrum salicaria</i> | 21.1 | 4.1 | | | | | | |
| | MESA | <i>Medicago sativa</i> | 2.3 | | 0.1 | | | | 0.8 | |
| | NECA | <i>Nepeta cataria</i> | 2.3 | | 0.4 | | 1.0 | | | |
| | ONAC | <i>Onopordum acanthium</i> | | 0.3 | 0.6 | | | | 0.8 | 0.5 |
| | PHLO | <i>Physalis longifolia</i> | | | | | 1.0 | 16.1 | 2.3 | 10.1 |
| | PLLA | <i>Plantago lanceolata</i> | | | | | 1.0 | 4.9 | | 0.7 |
| | PLMA | <i>Plantago major</i> | 10.2 | 0.3 | | 0.5 | 1.0 | 3.6 | | |
| | POAM | <i>Polygonum amphibium</i> | 1.6 | | 0.1 | 11.5 | | | | 2.4 |
| | RUCR | <i>Rumex crispus</i> | 0.8 | 0.3 | 0.1 | 1.0 | 2.0 | | 0.8 | 0.2 |
| | SAOF | <i>Saponaria officinalis</i> | | | | | 1.0 | | 1.5 | 0.7 |
| | SCAC | <i>Scirpus acutus</i> | 0.8 | 0.3 | | | | | | |
| | SODU | <i>Solanum dulcamara</i> | 7.8 | 0.3 | | | | | | |
| SOOC | <i>Solidago occidentalis</i> | 0.8 | | | | | | 2.3 | | |
| TAVU | <i>Tanacetum vulgare</i> | 7.8 | 0.3 | | | | | | | |

Appendix 2.1. (Cont.)

| Life-form | Code | Species | WR | BH | BM | BP | OM | HB | HM | SN |
|---|-------------------------|-------------------------------|------|------|-----|-----|------|-----|------|------|
| Perennial Forbs (cont.) | TRDU | <i>Tragopogon dubius</i> | | | 0.2 | | 1.0 | | 6.8 | 1.4 |
| | VEBL | <i>Verbascum blattaria</i> | 0.8 | | 0.3 | | 7.8 | 5.4 | | 2.1 |
| | VEBR | <i>Verbena bracteata</i> | 8.6 | 0.3 | 0.1 | | | | | 2.1 |
| | VETH | <i>Verbascum thapsus</i> | 0.8 | | 0.7 | | 2.0 | | 12.0 | 2.2 |
| Woody Species | ACSA | <i>Acer saccharinum</i> | 4.7 | 2.1 | | | | | | |
| | ALRH | <i>Alnus rhombifolia</i> | 5.5 | 0.3 | | | | | | 0.3 |
| | AMAL2 | <i>Amelanchier alnifolia</i> | | | 0.2 | | 2.9 | | 2.3 | 0.6 |
| | AMFR | <i>Amorpha fruticosa</i> | 5.5 | 4.5 | 2.9 | | 17.6 | 5.4 | 13.5 | |
| | ARTR | <i>Artemisia tridentata</i> | | 1.0 | 3.1 | | 5.9 | | 0.8 | 0.1 |
| | CERE | <i>Celtis reticulata</i> | | | 1.2 | | 13.7 | 5.4 | 17.3 | 18.0 |
| | ELAN | <i>Elaeagnus angustifolia</i> | 5.5 | 0.3 | 0.1 | | 2.9 | | | |
| | FRPE | <i>Fraxinus pennsylvanica</i> | 0.8 | | | | 1.0 | | | |
| | PRUN | <i>Prunus spp.</i> | | | | | 3.9 | | 1.5 | |
| | PUTR | <i>Purshia tridentata</i> | | | | | 1.0 | | 2.3 | |
| | ROWO | <i>Rosa woodsii</i> | 14.8 | | 0.3 | | 7.8 | | 5.3 | 0.2 |
| | RUDI | <i>Rubus discolor</i> | | | | | 5.9 | | 12.0 | |
| | SAAL | <i>Salix alba</i> | 8.6 | 9.3 | | | | | | |
| | SAEX | <i>Salix exigua</i> | 14.8 | 12.0 | 2.7 | 7.8 | 14.7 | 7.1 | | 3.3 |
| | SALA | <i>Salix lasiandra</i> | 2.3 | 7.9 | | 2.1 | | | | |
| | TARA | <i>Tamarix ramosissima</i> | 8.6 | 14.8 | | | | | | |
| | TORA | <i>Toxicodendron radicans</i> | | | 0.2 | | 12.7 | 3.6 | 9.8 | 3.7 |
| ULAM | <i>Ulmus americana</i> | 1.6 | | | | 1.0 | | 4.5 | | |
| ULPA | <i>Ulmus parvifolia</i> | | | 0.2 | | 1.0 | | | | |
| number of quadrats surveyed in each reach = | | | 128 | 291 | 905 | 192 | 102 | 56 | 133 | 1771 |

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CHAPTER 3: MODELED RESPONSES OF RIPARIAN PLANTS AND COMMUNITIES ALONG RESERVOIRS AND UNIMPOUNDED REACHES OF THE HELLS CANYON CORRIDOR

3.1. Introduction

The distribution and abundance of riparian vegetation are largely functions of hydraulic conditions (velocity and depth), substrate (the distribution of sediment particles), and the relationships between channel and floodplain geometry and flow patterns. These fluvial characteristics determine seasonal patterns of inundation and hydrograph recession rates. All these factors result from interactions between basin hydrology and geomorphology.

Thus, while other factors influence riparian vegetation and channel patterns, the primary relationships are between water and the earth's surface. Along some rivers, geomorphic processes are quite dynamic while along others they are more static; often punctuated by rare, dramatic events that alter the channel to varying degrees. Despite the differences in relative rates of geomorphic change, the river form created by these processes and the on-going interactions with flow dictate riverine hydraulics that play a primary role in enabling the distribution of riparian, or streamside, vegetation.

To evaluate the effects of a particular flow regime on vegetation along a reservoir and river system, it is necessary to predict the primary responses to hydrology, geomorphology and subsequently, vegetation. Predictions can rely on three different approaches including; 1) professional judgment that permits a semi-qualitative approach, 2) quantitative statistical projections based on empirical data, and 3) computer modeling based on underlying physical processes and ecological interactions. Each of these approaches has strengths and weaknesses and in practice it is generally best to apply a combined approach.

Simons & Associates (1990) developed a three-level process that incorporates qualitative geomorphic analysis, quantitative engineering and geomorphic analysis, and quantitative computer modeling analysis (see Figure 3.1.). This approach incorporates analyses of physical processes governing the flow of water, transport of sediment, development of river form and response, and interactions with vegetation that provide wildlife habitat. From the analyses, scientifically justifiable, hierarchical results are obtained. Each level of analysis builds on the interpretation developed by the previous level and during the iterative process inconsistencies are reconciled. This produces mutually supportive results. A benefit of this approach is that the geomorphic analysis provides a foundation for more complex analyses and promotes a general understanding as the other levels of analyses are conducted. In the present study, this modeling approach was applied to the reservoir and riverine reaches of the Hells Canyon Corridor from above Brownlee Reservoir downstream to the confluence with the Salmon River.

A number of prior studies applied modeling approaches to predict the impacts of flow regulation on riparian vegetation. One of the first such studies was conducted by Simons & Associates

(1990) in the 1980s for the Platte River. This analysis was part of the Federal Energy Regulatory Commission (FERC) relicensing process for Kingsley Dam and other hydropower generating facilities associated with FERC Projects 1417 and 1835. The model was calibrated with cross-sections surveyed during the 1920s and analyses of historic flow data from that period through the mid 1980s. Based on the channel geometry and flow data, the model first computed hydraulic conditions and then corresponding annual vegetation response. The model focused on establishment of vegetation during the seed germination season and subsequent growth or removal of vegetation due to scour that was based on flow-criteria. After demonstrating that the model was functioning properly on a conceptual basis, the calibration of the model showed that the model could successfully reproduce the response of vegetation at cross-sections along the North Platte, South Platte, and Platte rivers.

Thus, the Platte River models computed expansion of vegetation reasonably matched the actual expansion of vegetation as measured from a series of aerial photographs from the late 1930s to the 1980s. Figure 3.2. shows the computed width of the active channel as it diminished over time due to the encroachment of woody vegetation. The measured data from aerial photographs was generally consistent with the results computed by the model. Since the model that was based on fundamental physical processes and utilized actual data describing the channel and flow, succeeded in reproducing field patterns, reasonable confidence was gained in the applicability of this model as an analytical and predictive tool.

Subsequent to the Platte River study, similar vegetation modeling was conducted for a reach of the Snake River in Idaho from Swan Falls Dam to the Idaho/Oregon border as well as for another short reach at Dolman Rapids. Portions of this work were published in the scientific literature (Johnson et al. 1995), but no site-specific calibration of the model was conducted for that study.

Currently, a version of the vegetation model has been combined with a sediment transport model to evaluate the effects of flow regulation on the Platte River as part of the ongoing programmatic environmental impact statement (Murphy et al. 2001). It has been calibrated on a preliminary basis with reasonably good results. The expansion of vegetation over a 100-year period was duplicated reasonably well at several transects based on a comparison of historic mapping and aerial photography from the late 1800s to the mid-1980s. The significant expansion of vegetation versus active (or non-vegetated) channel at four cross-sections were: measured/modeled as 11%/11%, 22%/23%, 29%/33%, and 29%/29%, respectively. The model is currently refined for final calibration and verification before its application in an environmental impact statement.

A somewhat related vegetation model is being developed and utilized by Canadian researchers for BCHydro (British Columbia Hydro) to evaluate the effects of historic and alternative future reservoir operation plans for various portions of the Columbia River Basin in Canada. Discussion of this emerging model with those who are developing and applying it, indicates that the model considers the processes of plant germination and inundation. The model projects the spatial patterns of vegetation along reservoir shorelines in response to changes in hydrology and reservoir operations.

The general objective of the present study was to determine the physical factors that underlie current vegetation patterns along the Snake River corridor through Hells Canyon and then to apply a process-based model to predict consequences of future flow scenarios on riparian

vegetation. The specific objectives of the study were thus to: 1) analyze the historic responses of vegetation to inundation and regulated flows; and 2) refine and apply the Platte River model and interpret model outcomes to evaluate the probable responses of vegetation to proposed future operations.

3.2. Methods

We developed a computer model to calculate the establishment, growth, and removal of riparian vegetation based on hydraulic conditions imposed on river and reservoir banks by different operational scenarios. The model is named HC_REM (Hells Canyon_River Environment Model) and is the successor of the riparian vegetation model, CHANWID, that was developed for the Platte River (Miller et al. 2002) and applied to portions of the Snake River in the 1990s (Johnson et al. 1998). Most of the following discussion focuses on river reaches, but the same concepts apply to reservoirs except that water velocities of reservoirs are generally insufficient to scour vegetation. Variations in flow and water level directly affect vegetation and observed vegetation patterns can be related to water level fluctuations throughout the seasons and the years (Nilsson and Jansson 1995, Nilsson and Keddy 1988, Hill et al. 1998, Jansson et al. 2000).

For the riparian vegetation model it is necessary to consider the physical and biological processes that underlie the linkages between water pattern and vegetation establishment and mortality. For establishment, seeds (or vegetative propagules) must have sufficiently moist substrate. After germination the vulnerable seedling must survive through a variety of challenges including drought, scour and flooding.

Timing is critical and seeds produced by riparian vegetation often germinate in the late spring and early summer, although some plants, particularly herbaceous species, have alternate seasonal phenologies (described in Chapter 2). During the period of seed production, dispersal, and germination, the snowmelt peak often occurs and recedes. When receding flows expose suitably moist substrates, seeds are deposited, often by wind or by floating on the water surface to the bank edge. Some of the seeds germinate and seedlings become established as roots grow into the soil substrate, and continue to grow through the summer season if moisture in the root zone is sufficient. The timing of seed production is thus naturally associated with the typical timing of peak flow, and its recession. This provides a general reproductive strategy for survival and expansion of many riparian species. Thus, successful establishment of vegetation is influenced by the timing of the hydrograph peak and associated recession.

The germination process is also affected by the availability of suitable substrate. Roots can readily grow into a medium consisting of sand and finer sediment sizes. Roots can grow into coarser substrate if sufficient finer sizes are also present. Seedlings typically cannot grow and survive on very coarse material unless finer material is also present. Vegetation cannot grow into bedrock except where sufficient cracks have formed into which finer materials have been deposited. The HC_REM considers the type of substrate and the potential for root growth into the various types of substrate.

Consequently, a number of factors can limit survival of seedlings after germination and establishment. As the summer proceeds, the plants may not survive if the roots cannot grow

rapidly enough to maintain contact with moisture that is often provided by the capillary fringe above the riparian water table that represents a (near) horizontal extension from the stream. During high flow events that may occur during the summer season with intense rain events, newly established vegetation can be eroded from the substrate. This potential scour depends on the flow magnitude, associated extent of inundation, and the flow velocity that can scour vegetation and/or underlying sediment. As the peak flow occurs the next season, vegetation may be also be scoured although older plants generally become more secure. The cycle is repeated year after year and responds to the dynamic hydrologic inputs and associated processes of sediment transport and geomorphic condition.

To consider these processes, the model cycles through sequential time steps and vegetation subroutines assess potential plant establishment, growth and removal. If vegetation is established and survives, each month the vegetation becomes one month older. If vegetation is removed, the vegetation-tracking variable is reset to zero for each particular species and point in the cross-section, leaving barren substrate. The model can focus on individual species or various species can be grouped together on the basis of their shared growth form and life history strategies. Thus, a combination of species of a particular life history type, such as hydrophytes or obligate riparian perennials, can be modeled.

3.2.1. General Discussion of Model Components

Germination/Growth

The germination/growth subroutine determines whether or not plant seeds can germinate at particular positions along river/reservoir cross-sections. On a weekly basis, the model allows germination to occur, but only during the seed viability period for the species or group (this viability period is referred to here as ‘dispersal’). Thus, for each week of the year a variable is set for each life form that either allows or precludes germination. Vegetation is limited to those areas of the cross-section that are not inundated during the germination season and that have recently been exposed as the water recedes leaving moist, barren substrate. New vegetation is precluded from germinating if that particular species has already been established at that location. Once established, seedlings begin to grow. Growth processes can be halted by subsequent sources of mortality.

Plant Competition

While the model excludes future establishment of the same species at a particular position, multiple species (or assemblages, depending on how the model input has been set up) can germinate at the same location. Thus, the current model does not incorporate plant competition and consequently the model potentially inflates the extent of vegetation recruitment at a particular point (quadrat). Although competition between species is not incorporated in the model, competitive interactions are subsequently qualitatively addressed in the interpretation of results. Further, abiotic interactions appear to exert a stronger influence upon plant distribution in these environments and the influences of competition are probably consistent across operational scenarios, thus comparative analyses remain valid.

Inundation-induced Mortality

Vegetation can be removed by inundation-induced mortality. Criteria for lethal inundation are set by life form since some species or assemblages are more sensitive to inundation than others. For each species, the maximum length of continuous inundation is set and beyond that the plant dies. The designated sensitivity to inundation is also variable with age of vegetation.

Desiccation-induced Mortality

Vegetation can be removed by desiccation if the water table recedes faster than the roots can grow, leaving the plant without sufficient moisture for survival. Allowable rates of water level recession are set for each species of vegetation and for several age categories within each life form. Because Hells Canyon is steep-sided, the riparian zones are very limited in distance away from the river or reservoir and for these zones, the riparian water table is considered to represent a horizontal extension from the adjacent water stage. This hydraulic analysis was inappropriate for tributary deltas where the riparian water table is jointly recharged by the river and tributary stream. This influence was recognized in the interpretation of the model output.

Scour-induced Mortality

If scour of the substrate surrounding the root zone is sufficient or if sufficient force is exerted on a plant by the flow, the plant can be removed. A maximum allowable velocity criterion is used, beyond which vegetation is removed. Controlling parameters are set for each type of vegetation and different allowable velocity criteria are set depending on the species or life form of vegetation and age.

Time Period

The time period over which analyses and future projections were analyzed was previously addressed in the development of inflow hydrology (Simons et al. 2001). Simons et al. (2001) concluded that vegetation responds to the environment over periods of decades and relatively infrequent events such as floods with return periods of 5 to 10 years significantly impact the vegetation recruitment process (Mahoney and Rood 1998). Even larger and less frequent events may be required to scour vegetation or to produce potential geomorphic changes that, in turn, affect vegetation. Therefore, for vegetation analyses, the length of time to be modeled should be several decades or longer.

Miller et al. (2002) further recommended that the length of time to be modeled should be about 5 to 10 times the recurrence interval of the parameter to be measured. Thus, for vegetation recruitment in association with flood peaks that have a return period of 5 to 10 years, the recommended trace would be 25 to 100 years long. Following from these recommendations, inflow hydrology developed for Hells Canyon Complex studies included a record of flows that covered a period of 72 years. This was based on adjustments to historic flows (1928–1999) by IDWR to account for changes in historic basin-wide water resources development and changes in basin-wide project operations (Simons et al. 2001).

Time Step

The selection of an appropriate time step for the modeling raised a number of considerations. The vegetation modeling should involve a time-step that is both ecologically defensible and technically feasible. Following consideration of the relevant ecophysiological processes and

evaluations of previous modeling exercises, we determined that a weekly time-step would be appropriate for the vegetation modules. A coarser time-step such as modeling on a monthly or multiple monthly basis would sacrifice some accuracy and would be less responsive to 'ramping' rates; the rates of river stage recession that influence seedling survival. While finer resolution analyses could be based on daily or even more detailed time-steps, we considered it unlikely that such analyses would improve the accuracy of the vegetation modeling. Further, such detailed modeling would imply a level of precision that cannot be achieved due to the stochastic processes ('chaos') inherent to ecological processes.

The modeling time-step should reflect the temporal patterning of relevant biological processes. In particular, plant phenology, the seasonal timing of the developmental sequence, and life history, the period and sequence required to complete the plant life-cycle, should be considered. Both phenology and life history vary substantially across plant species that occur in the riparian zones along reservoir and riverine reaches of the Hells Canyon region. With respect to life history, some annual species complete their life-cycle within a period as short as about 10 weeks. More commonly, the annual species would require 20 to 30 weeks for their life cycle. Biennial species require two growing seasons while perennial plants may live for a few years or up to a century or longer. With respect to life history, the specific life-cycle duration cannot be predicted down to the level of number of days and for many perennial species it cannot even be predicted to number of years. Thus, with respect to plant life history, a weekly time step is adequate.

The duration of particular phenological stages also supports the weekly time-step. The establishment of new plants requires the production and dispersal of seeds, followed by their successful germination and establishment. The period of seed release varies across plants, such as from about 4 weeks for the coyote willow (*Salix exigua*) to more than 6 months for salt cedar and some other riparian plants (Shafroth et al. 1998). The period of seed viability also varies, from a low of about 4 weeks for willows and cottonwoods to the condition for many species in which seeds remain viable for one or more years. The combination of the period of seed dispersal, plus the overlapping period of viability produces the period of 'seed availability' that is central to the modeling of seedling recruitment. This period of seed availability will vary from about 6 weeks for willow to year-round for a number of plant species along the Snake River and reservoirs in the Hells Canyon area. This duration of phenological stages also supports selection of the weekly time-step.

The detail of the time-step consideration for flow operational scenarios evaluation has been considered in analyses of other river regulation projects. Following a comprehensive analysis of the life history and phenology of cottonwoods, we concluded that a weekly time-step would be appropriate for evaluating the potential effects of different operational scenarios for the Oldman River Dam in southwestern Alberta (Mahoney and Rood 1983). A decade later, actual vegetation responses have been very similar to those predicted using a weekly time-step model (Rood et al. 1998). Following the precedent of the Oldman River Dam, a weekly time step for modeling of riverine and riparian processes has become the norm for joint federal and provincial environmental assessment reviews for river management projects in Canada (Wagner 1996).

The sophistication and detail of riparian models and river flow operational scenarios evaluations have increased over the past decade. Previously, some modeling exercises would simply consider single stream flow values such as mean discharge, with evaluations over a period of simulation

for a number of decades. More refined analyses followed in which monthly discharge values were considered and subsequently, a few studies such as the Oldman River Dam evaluation invoked a weekly time step.

For the Montana Power Company Inc. final license application to the Federal Energy Regulatory Commission (FERC), Scott et al. (1993) focused on peak discharge. That group recognized that seasonal flow patterns were important (Scott et al. 1993) but this concept was not translated into a detailed modeling component involving ‘real-time’ simulation.

The GIS-based flow Operations evaluation for the Snake River reach below the Swan Falls Dam and another reach at Dolman Rapids preceded the present study and successfully combined hydrologic modeling with subsequent assessments of riparian vegetation response. These modeling efforts utilized the same type of hydrologic input as the original CHANWID model which was based on two flow values per year, the peak annual flow and the mean monthly flow in June.

Other research groups are working towards the development of integrated hydrologic, geomorphic and riparian vegetation models, although we are unaware of any that match the present level of development in HC_REM. Springer et al. (2001) introduced a model that couples groundwater and riparian vegetation to evaluate proposed reservoir regulation patterns. That model provides vegetation assessment with a 3-month time-step.

We have recently evaluated actual field recruitment of riparian vegetation following a natural flood that was followed by the deliberate imposition of ramping flow recession from existing dams (Rood et al. 1998). These analyses involved three-day moving average hydrologic data, and thus effectively imposed a half-week time-step. The three-day time step was considered appropriate since there are always some lag associated with infiltration and drainage between the river and riparian water table. Because substrates do not dry out instantly and due to the presence of the capillary fringe, there are some hydrologic factors that diminish the immediate impacts of changes in stream stage, and particularly the effects of declining stages. The occurrence of these hydrologic interactions also discourages a very short time-step in the modeling exercise. Consistent with this view, for historical analyses of relationships between riparian vegetation and regulated stream flows in Arizona, Shafroth et al. (1998) imposed a 7-day lag for hydrologic patterns. This modeling exercise provided a reasonably good fit with the observed seedling recruitment of riparian vegetation including cottonwood, willow and salt cedar, further supporting the use of a weekly time-step that would recognize the latency of some hydrologic and ecophysiological responses.

Thus, we determined that a weekly time-step was appropriate for the present modeling of riparian vegetation, since:

- (1) It would be impossible to model plant phenology in a natural ecosystem to a finer level of temporal detail,
- (2) A number of hydrologic components involving infiltration, drainage, drying and capillarity, ‘buffer’ short-term changes in stream stage relative to the impacts on riparian vegetation,

- (3) Other physical processes and particularly temperature variation influence ecophysiology and prevent more precise vegetation modeling, and
- (4) A weekly time-step has been previously determined to be suitable for the evaluations of proposed river flow operational scenarios with respect to riparian vegetation.

However, while a weekly time step is appropriate from vegetation phenology, ecophysiological, and practical perspectives, such a time step does not directly consider the potential effect of short-term variations in flow and water surface elevation that results from power peaking in hydropower operations. This could be particularly relevant for the Hells Canyon reach of the Snake River since daily flow fluctuations accompany hydropower generating operations. Thus, while the vegetation modeling generally utilizes a weekly time-step, more detailed stream flow (stage) data have been incorporated into the model. For different modeling components, the weekly maxima, mean and minima are used, as appropriate based on mean daily data. A simple weekly mean would not be appropriate for many vegetation processes such as initial establishment that is more accurately related to the maximum water stage and draw down of the water surface within the week. Likewise, the rate of recession of the water surface correlates closely to plant desiccation and is a key component of the model, which considers the rate of water surface elevation drop from the peak of the week to the end of the week. Vegetation exposed to scouring flows tend to be progressively more vulnerable to removal by higher flows such as peak flows (both on a short-term basis such as the peak flow of the week, as well as annual peak flow). The model therefore utilizes the peak weekly flow to test vegetation survival by this mode of removal. As a result of this finer disaggregation of the weekly time step into its key aspects, and incorporation of these fluctuations into the vegetation process algorithms, the model appropriately considers a broad range of water level fluctuations into the modeling process.

In addition, since the calibration process used historic data with the same time step as future operations, the model parameters implicitly include a similar level of fluctuation in modeling future response. Thus, if future ramping rates are similar, this level of flow fluctuation is implicitly incorporated in the model. To the extent that ramping rates are somewhat reduced, the model may slightly under-predict the extent of future vegetation. In any case, the issue of modified ramping rates on vegetation is expected to be small since most of the fluctuations occur at flow levels that are frequently below the elevation zone where vegetation is established.

3.2.2. Model Parameters

Specific parameters within the various subroutines in HC_REM that simulate the establishment, growth, and removal of vegetation are presented in the following sections.

Germination and Growth

Initial condition for vegetation are input data for the model, which are typically set to zero. Thus, no vegetation exists at any point in any transect when the modeling starts. Initial conditions can be modified, however, whereby the type and age of vegetation are specified at any points in a transect or cross-section. Each year, the age of each type of vegetation at each point is

numerically summarized. A zero means no vegetation of that type exists at that point while any non-zero numerical value gives the age of any vegetation at each point.

The germination/growth subroutine determines whether or not and where vegetation can germinate. The model allows germination to occur only during the seed germination period for each type of vegetation, which can be set at either 0 or 1 for each week of the year and for each life form. A zero indicates that no germination for that particular species occurs during that particular time interval. A one indicates that germination is possible for a given time step and for a given species or vegetation category. Germination is not allowed at any point where a given species or vegetation category already exists, but multiple species can germinate at a given physical location. The model does not consider competition between plant species.

Vegetation establishment is limited to those areas of the cross-section that are not inundated during the germination period or that have recently been exposed as water levels recede leaving moist, barren substrate. Typically, the germination and flow recession periods coincide. The model computes the water surface elevation for the maximum flow during the week and the end of the week, based on mean daily flow from the hydraulics model. This difference in elevation is the vertical band within which seedlings can germinate. This elevational band can be adjusted using two input parameters; these parameters determine the lower and upper limits of germination above the maximum water surface elevation for the week or below the water surface elevation at the end of the week, respectively.

Two parameters are used to set germination requirements because plants propagules require a range of germination conditions, categorized in the upper or lower elevation zones. One parameter evaluates germination in the lower portion of the elevation zone based on hydraulic conditions. The other parameter sets germination in the upper portion of the elevation zone. Establishment of vegetation is further limited by a parameter that either allows (1) or precludes (0) vegetation.

The substrate is defined for each point in a cross-section or transect. Four types of substrate were selected to represent the range of conditions for the Snake River. These substrate types were: (1) bedrock, (2) boulders and coarse cobble without any sub-layer of fine-sized sediment (sand or finer), (3) coarse material (boulders, cobbles, or gravel) with a sub-layer of finer particles, and (4) fines. Root systems either cannot penetrate into rock or cannot survive in a substrate that does not have sufficient fines. Substrate that consists either entirely of fines or has sufficient fines to allow root growth and sustainability provide a significantly better medium for vegetation. A model parameter limits the establishment of vegetation based on the type of substrate available for germination (0–1 scale).

Once seedlings are established, root- and stem-growth are computed based on variable weekly growth rates. The growth rate is set at zero when the plant is dormant and at non-zero values during the growing season. Depending on life form, the water table or capillary fringe above the water table potentially limits root growth. Thus, the root tip grows into the capillary fringe, but generally does not extend in saturated soil. A parameter defines the height of the capillary fringe zone above the water table for each type of substrate and life form. (However, in willows, roots can extend into saturated soil i.e., the water table). The model tracks the existence of each plant

type and age at each point, as well as the status of root and stem growth. If a life form dies, all plant components are removed, including the root.

Inundation

Inundation can kill (i.e., remove) life forms. Life form and age have different tolerances to inundation. Typically younger age classes are less tolerant than older ones. The maximum length of continuous inundation is set for each life form and age. If this length of time is exceeded, the plant dies (i.e., removed from that particular location along the transect). This parameter can be further refined by incorporating substrate type; coarser grained substrates drain more rapidly than finer grained substrate, thus affecting plants differently.

Desiccation

Vegetation dies as the water table and capillary fringe recede faster than the roots can grow, leaving the plant without sufficient moisture for survival. The rate of water surface decline is computed by the difference between the maximum water surface elevation in succeeding weeks. No mortality occurs without a decline in water surface elevation. This can only occur during the growing season. Vegetation dies when the water level recedes for a pre-determined length of time below the root zone (i.e., drought tolerance). The drought tolerance is different for each life form and age category, although substrate effect are not incorporated in the model.

Scour

Scour is defined as the hydraulic forces that are sufficient to remove vegetation or rooting substrate. The parameter uses an allowable velocity-based criterion. Vegetation is scoured (i.e., removed) when the mean velocity in the channel cross-section exceeds the allowable velocity for each life form and age.

Vegetation Accounting

Hydraulic modeling is conducted on a mean daily basis. For a large-scale watershed such as the Snake River, this level of detail is considered more than sufficient since vegetation response to flow changes occurs over a longer time frame. Vegetation modeling accounts for minimum, maximum, and mean flow characteristics that occur on a weekly basis. Vegetation presence is summarized on a yearly basis, including the frequency and mode of mortality.

Model Testing

Testing of individual model subroutines was conducted to ensure adequate responses at a conceptual level prior to the calibration/verification process. Testing was completed for the combined sediment transport and riparian vegetation model. A similar methodology was used for a vegetation model developed for the Platte River (Murphy et al. 2001).

3.3. Life Forms—Life History Traits, Vegetation Groups and Modeling Parameters

We sampled vegetation at cross-sectional belt transects as described in Chapter 2. The flora at these transects was composed of 211 plant species; 15 of these were non-vascular plants or plants that could not be identified to species. Thus, 196 vascular plants were identified with approximately equal numbers of native (99) and exotic (97) species (Appendix 3.1).

Plant abundances were determined in the riparian zones for each of the study reaches. Dominant species were selected that occurred in defined elevational zones, with distinct life history traits. We conducted this initial screen to characterize local species and establish criteria for different plant life forms. This initial vegetation screen provided direction for the selection of life history characteristics that would be critical for the vegetation modeling in HC_REM. The plants initially selected were *Amorpha fruticosa* (false indigo), *Celtis reticulata* (netleaf hackberry), *Glycyrrhiza lepidota* (American licorice), *Polygonum amphibium* (water smartweed), *Populus trichocarpa* (black cottonwood), *Salix exigua* (sandbar or coyote willow), *Tamarix ramosissima* (salt cedar), and *Xanthium strumarium* (common cocklebur). We conducted a literature review for each species to determine: origin (native or exotic), water requirements, drought and inundation tolerance, site requirements, reproductive strategies, seed dispersal and germination phenology, responses to disturbance, and contributions to wildlife habitat (Appendix 3.2).

Based on the literature review, a narrower set of autecological life history traits for 47 species were developed for vegetation modeling of the Hells Canyon Corridor (Table 3.1.). Species were grouped relative to common life history traits. Seed dispersal and germination phenologies were assessed and plant species classified into five germination classes: 1) all-season, 2) spring, 3) spring and autumn, 4) summer, and 5) autumn (Figures 3.3. and 3.4.).

We determined that the range of life histories could be reasonably represented in six broad categories. We recognize that this aggregation would obscure some patterns, but considered that this of resolution would be relative to the precision of modeling outputs.

Designations of the six plant groupings (i.e., life forms) were based on two criteria: the length of the life cycle of individual plant species (i.e., *perennial* versus *annual*) and hydrological dependency (i.e., facultative versus obligate riparian plant species). *Facultative riparian plants* are those species that also occur in upland areas but are promoted by the additional moisture (and other factors) in the riparian zone. In the Hells Canyon corridor, netleaf hackberry is a typical example of a facultative riparian plant. Hackberry exists in the upland as scattered shrubs, trees or clonal patches but is more abundant in the riparian zones where it often occurs in arcuate bands at specific elevations above the river or reservoir. In contrast to these facultative riparian species, *obligate riparian plants* are generally restricted to the riparian zones and are absent from the upland zones, except in areas of water seeps or other positions with supplemental moisture. In the Hells Canyon corridor, the true willows (*Salix* species) and particularly the sandbar or coyote willow, *S. exigua*, are examples of this life history type. In general, the obligate riparian plants are more inundation-tolerant but less drought-tolerant than the facultative riparian plants. Facultative riparian plants are typically more inundation-tolerant but less drought-tolerant than upland species.

The combinations of annual versus perennial and facultative versus obligate constitute four categories that are central to riparian vegetation communities: facultative riparian annuals, facultative riparian perennials, obligate riparian annuals and obligate riparian perennials. The riparian perennials, both facultative and obligate, include the larger woody plants, shrubs and trees that provide structure (vertical complexity) critical to wildlife habitat.

To complete the range of typical life-history patterns two additional vegetation groups were established. *Hydrophytes* are very inundation-tolerant and drought-susceptible. These plants require well-watered sites and can generally sustain physiological function as emergents. Within the Hells Canyon corridor, *Polygonum* species (water smartweeds) and the yellow iris comprised the most common hydrophytes.

Finally, *ruderal annuals* are weedy species with the capacity to germinate through much of the growing season over a range of environments. This group contains many exotic species, including some invasive and noxious species. The common cocklebur is an example of this vegetation group that was abundant through most of the Hells Canyon corridor.

We categorized each plant species identified in the field into these six vegetation groups, based on their life-history characteristics and more importantly, on their relative elevation over mean water level along the river and reservoirs, as determined by field studies (Table 3.2.). Some species were rarely encountered and insufficient data were available for an accurate assessment.

3.4. Modeling of Reservoir Shorelines

One hundred vegetation transects established along reservoir shorelines were used in the vegetation modeling. HC_REM model was run using the transect geometry, substrate conditions, and mean daily historic water-surface fluctuations as input variables. Vegetation was absent at the start of the model run. The model was run over a period of several decades to produce a vegetation pattern. The modeled vegetation patterns composed of the six life forms were compared with the observed pattern in the field at each of the vegetation transects. This constituted the calibration and verification process.

3.4.1. Model Calibration and Verification

The HC_REM model was calibrated using historic operations (Parkinson 2002) for the three reservoirs of the Hells Canyon Complex on the Snake River. Appendix 3.3 presents historic water level fluctuations for the three Hells Canyon reservoirs in relation to daily, seasonal, and yearly inflows. Water level fluctuations resulting from historic operations were used as input to the model along with shoreline geometry and substrate conditions for each transect. Vegetation was absent at the start of the model run. The model was run with several decades of historic water surface elevation data, to determine whether the model can reproduce the vegetation pattern observed in the field.

In calibrating the model, environmental parameters governing the interaction between water level variations and vegetation were developed for each life form using field data from all reservoirs. Parameters were adjusted to achieve a reasonable match between field data and

simulated vegetation patterns for each of the six life forms for the reservoirs grouped together by the end of the calibration period. Different life forms tend to establish and survive within distinct elevation bands along reservoir shorelines. These bands correspond to seasonal hydroperiods. Thus, the most significant factor in comparing the model results to the field data was to develop parameters where simulated vegetation patterns reasonably matched the elevation range of field data. The field data sets were summarized in graphical form, showing the elevation distribution of vegetation with respect to full pool level at one-half meter vertical increments (Appendix 3.4).

The first assessment of model results compared the overall elevation distribution of the six life forms pooled for all reservoirs (Table 3.3.). Vegetation distributions were summarized in 0.5-meter increments above reservoir full pool level.

The elevation range of the modeled vegetation patterns closely corresponds to the field data for each life form. Extreme low and high levels of vegetation define the elevation range of the band for each life form generally within 0 to 0.5 meters. The total range of occurrence for each life form spans 7 to 14.5 meters. The largest discrepancy observed was at the lower elevation range for hydrophytes (Table 3.3.).

The percentage of points that become vegetated as determined by the model within the elevation zone of actual field vegetation data was closely evaluated (Table 3.4.).

Thus, actual and modeled distributional patterns of life forms matched very closely. Model and field results were compared on a reach-by-reach basis for each life form. Table 3.5 presents a summary of the absolute differences in elevation (m) between the modeled results and the field data.

The elevational range of modeled vegetation would exactly match the range observed in the field, if each of the cells in Table 3.5. was zero. Generally, the range of modeled distributions deviate 0–0.5 m from actual life form distributions, although in some cases larger deviations were found. Note that there is not a systematic –either positive or negative– difference in elevational distribution between modeled and actual vegetation distributions for each of the reaches (Table 3.5.). Furthermore, the model could be improved by using reach-specific parameters, rather than generalized parameters (i.e., generalized for the entire study reach). It is preferable, however, to use uniform parameters across all study reaches, as the same life form should respond to environmental parameters similarly in different locations.

The percentage of modeled points placed within the correct elevation band, based on field data collected for each life form, reach, and subreach is summarized in Table 3.6.

Generally, model outputs resulted in at least 80 to 90 percent conformance with field results. In general, the model accurately described the distribution patterns of perennials (both obligate and facultative) and ruderal annuals other than riparian annuals, remarkably well. Exceptions were the Oxbow Bypass reach and the Powder River Arm of Brownlee Reservoir. Other environmental factors may affect plants in these two reaches, but do not lend themselves to this modeling analysis. Furthermore, smaller sample size for less common life forms may also adversely affect overall results.

Given the strong conformity between field- and modeled results, the model was considered to be reasonably well-calibrated and verified, and ready for evaluation of the operational flow scenarios.

3.4.2. Scenario Results

The HC_REM model analyzed the effect of two operational scenarios on vegetation distribution. These scenarios are: 1) Idaho Power Company's (IPC) proposed operation (proposed) and, 2) Full pool or 'Run-of-River' (ROR) operation. The ROR keeps the reservoirs full at all times and passes the upstream flows through the reservoir system. The water level variations and releases for the proposed operations were modeled by IPC using the CHEOPS™ model. Further details on these operational scenarios (proposed—and ROR operations) are provided in Chapter 1.

The HC_REM model was calibrated and verified for the reservoir reaches of the Hells Canyon Complex as described in the previous section. Often, investigators compare the modeled results under historic conditions with the model results under each flow scenario. This provides direct model-to-model comparisons that can be used to demonstrate change in outcome based on a consistent methodology. This approach avoids discrepancies in absolute differences between the actual field data under historic conditions and the model results calibrated under historic conditions.

A comparison in average water levels in Hells Canyon Reservoirs among Historic-, proposed-, and ROR scenarios shows relatively little difference between the historic and proposed operations, but large differences relative to the ROR scenario (Table 3.7.).

On average, the proposed operations for Brownlee Reservoir results in water levels similar to Historic Operations. However, there is about a 17-foot difference in water levels with the ROR—compared to historic operations. For Oxbow the increase in average water level is about 1.3 feet for the proposed operations and 2.9 feet for the ROR—compared to historic operations. In Hells Canyon Reservoir, increases in water level for the proposed—and ROR operations are 1.8 and 2.6 feet, respectively.

To better understand the effect of these flow scenarios, water surface elevations were summarized over time (Appendix 3.5.). Only graphs for the proposed operations were prepared since the ROR operations is simply a constant water surface elevation at the full pool level.

3.5. Modeling the Snake River

Ninety-two vegetation transects along this study reach were used in the vegetation modeling. We ran the HC_REM model using the riverbank geometry and substrate conditions at vegetation transects and mean daily historic water-surface fluctuations as input variables. Vegetation was absent at the start of the model run. The model was run over a period of several decades to produce a vegetation pattern. Six life forms were evaluated in the modeling, as described earlier.

We compared the modeled vegetation pattern composed of the six life forms with the observed vegetation pattern in the field collected at each of the transects. This constituted the calibration and verification process that will be described in more detail below.

3.5.1. Model Calibration and Verification

Hydraulic modeling was conducted along the Snake River to develop water surface elevation and velocity information at vegetation transects for historic-, proposed and ROR operations. Input to the hydraulic model consisted of cross-section data, defining the channel geometry and downstream slope, and a time series of flow data at the upstream boundary of the model. The hydraulic model computed the water surface elevation and velocity of flow as dictated by the interaction between channel geometry and resistance to flow, using upstream flow data. The channel geometry for the Snake River downstream of Hells Canyon Dam was based on a combination of bathymetric and topographic surveys (Parkinson et al. 2002).

Model calibration consisted of running the model using recent historic hydrology for which pressure transducer data was available to obtain a reasonable match between computed and observed water surface elevations. The calibration run spanned low to relatively high flow conditions to ensure that the model could produce reasonable results for a wide range of historic and operational flows. We graphically evaluated the comparison between computed and observed water surface elevations (Appendix 3.6.). The comparison of measured and observed stage hydrographs shows good congruence, often with differences on the scale of a few tenths of a meter. Input flows were run to calculate water surface elevations at the vegetation transects for the weekly and sub-weekly flows corresponding with the needs of the vegetation model. Historic flow data at the Hells Canyon gage are presented in Appendix 3.7.

We modeled the six life forms in the downstream reach. In calibrating the vegetation model, environmental parameters governing the interaction between water level variations and vegetation were developed for each life form using pooled field data from all transects. We adjusted parameters to achieve a reasonable match between field data and simulated vegetation patterns for each of the six life forms for differing geomorphic surfaces.

Different life forms tend to establish and survive within distinct elevation bands along riverbanks. These bands correspond to varying seasonal hydro-periods. Thus, model parameters were developed through the calibration process to match simulated vegetation patterns and field data (Appendix 3.8).

The modeled and field vegetation patterns were compared with respect to water surface elevation (Table 3.9.). The vegetation distributions were developed with respect to the long-term mean water surface elevation in 0.5-meter increments.

The elevation range of the modeled vegetation patterns corresponded closely to the field data for each plant life form. The range in elevation for each life form of vegetation differs in relation to species-specific life histories. The total elevation range for each life form varies from 7 to 12 meters. The model results for the low elevation boundary of vegetation matches the field data for all life forms. The model also matches the upper elevation boundary for 4 of the 6 life forms.

For the remaining vegetation groups, the discrepancy was 0.5 m low for one and 1.5 meters high for another (Table 3.9.).

The percentages of vegetated points based on model results that lie within the elevation range of the field data are presented in Table 3.10.

Thus, for 5 of the 6 life forms groups, all of the vegetation generated by the model occurred within the actual elevation range of the field data. For obligate riparian perennials, the model slightly over-predicted the upper boundary of vegetation but 99.7% of the modeled vegetation was within the field data range.

To improve modeling accuracy, transects were grouped according to substrate and compared for each life form in the calibration and verification process (Table 3.11.).

The elevational range of the modeled vegetation would exactly match the range observed in the field if the values of each of the cells were zero (Table 3.11.). While a number of the ranges match reasonably well, some departures are apparent. However, most points fall within the range of predicted and observed vegetation. The extent of matching of predicted and observed points provides another basis for evaluating the results. Table 3.12. presents the percentage of modeled points that are situated within the elevation band of the field data for each vegetation and substrate type.

The vegetated points for the sand/fines and coarse with fines substrate categories predicted by the model matched well with the observed data. The results became progressively less accurate with coarser substrates, particularly rock. This is not entirely unexpected since vegetation is found growing in small pockets of finer substrate within the more dominant but coarser substrate. Given the reasonably good comparison between field and modeled results, the model was considered calibrated and verified, and suitable for application in the analysis of operational scenarios.

Despite these results, however, a decision was made to refine the calibration by segregating individual quadrats by substrate type rather than using a dominant substrate for each transect. Tables 3.13. and 3.14. present the results of the refined calibration process.

In running the various Operations, the HC_REM model starts with an initial condition at which transects are devoid of vegetation. The first step in the modeling is to replicate the existing pattern of life forms (“current condition”) as was done in the calibration process. The next step is to use the input hydrology, modified by the proposed and ROR operations, to simulate new vegetation patterns. Thus, the initial condition used in HC_REM in these simulations is the current vegetation pattern. The total length of simulation runs were 110 years.

3.6. Results and Discussion

3.6.1. Considerations for Interpretation

3.6.1.1. Plant Species in Life Forms

Modeling outputs focused on the six life forms. The six plant groupings include a number of different native and exotic plants with similar life-histories that typically co-occur in particular elevational bands along the river and reservoirs. As discussed in Chapter 2, categorization of plant species were based on both published life-history information of these plants and empirical data collected along field transects in Hells Canyon Corridor (see Chapter 2).

However, some ambiguity exists in the assignment of facultative versus obligate riparian plants. Traits of these life forms are likely to be genetically-based with a range of life-history strategies existing. The life-form groups are further complicated by the abundance of exotic species in the Hells Canyon Corridor. Exotic plants may initially colonize riparian zones due to their specific life history traits, such as water-based dispersal of seeds or vegetative propagules (hydrochory). Furthermore, these invading exotics may be capable of subsequent expansion into the upland zone. Such plants would be initially assessed as obligate riparian species, but over a longer time period would be subsequently assessed as facultative riparian species. We assigned each of the common plant species to one of the six life forms (Table 3.8.), recognizing this potential ambiguity.

3.6.1.2. Plant Competition is Not Incorporated in HC_REM

As described in the preceding sections, the model considered hydraulic and geomorphic requirements for plant establishment and survival. However, the model did not incorporate plant competition. In the field there would be inter- and intra-specific plant competition, with the interspecific competition occurring within and across the vegetation groups. The patterns of plant competition would generally be consistent across different patterns of operational scenarios. Thus, the absence of a competition component in the model should not significantly distort the relative vegetation patterns across operational scenarios. Although incorporation of competition would have been desirable, the differing dominance and successional relationships are not fully understood for the numerous species observed in the Hells Canyon Corridor. Thus, the incorporation of plant competition and interaction was beyond the current capacity of modeling for these riparian plant communities and, in fact, the current vegetation modeling capabilities.

While the omission of plant competition does not affect the suitability of the modeling approach, output results were interpreted in the context of potential competitive interactions. Without competition, plant colonization would persist in response to the hydrologic patterns, somewhat unhindered by existing vegetation at the same location. Thus, modeled plant abundances are artificially inflated relative to the expected future plant abundances. In addition, specific circumstances exist in which the model results may be biased. We discuss these specific circumstances in detail where appropriate.

The magnitude of the inflation of plant abundance can be revealed by a comparison of the output results from the modeling of an extension of Historical Operations versus the actual current

vegetation distribution (Figure 3.5.; the same figure format provides the basis for much of the subsequent analysis.) We present six graphs; one for each of the life forms. These graphs are arranged according to the elevational distribution of the life forms (i.e., from dry to wet). The only exception is for the hydrophytes that would be situated below the obligate riparian plant form. The bottom vegetation group, the ruderal annuals represent the most opportunistic plant group that can colonize broad elevational ranges within the riparian zone. For each life form, the horizontal axis indicates the elevational position of the life form in relation to water stage of the reservoir or river. We use a small horizontal offset to enable visualization of the actual and modeled values, but this does not indicate an elevational offset of the two data points.

The vertical axis expresses the proportion of quadrats that are predicted to contain plants of the life form for one of the two operational scenarios (i.e., proposed–, and ROR operations). This provides an indication of the anticipated extent of distribution and a measure of relative abundance, but not vegetative cover of the life form.

The number of quadrats we modeled at a particular elevational position and reach is listed at the top of the first figure. At low elevations (left side of the plots), the numbers are often zero, since these positions would have been submerged during field sampling. For the higher elevations (right side of the plots), the numbers of quadrats sampled decline, because the vegetation shifted into the adjacent upland zone. At these elevations the obligate riparian annuals and perennials and the hydrophytes were not found in the local plant assemblage. However, facultative riparian plants and some weedy ruderal annuals would generally persist beyond these positions up the valley slopes.

The number of quadrats sampled provides some measure of confidence in the modeled prediction at that position. We considered sample sizes (i.e., number of quadrats sampled) < 5 to provide uncertain predictions; sample sizes ≥ 10 provide relatively accurate predictions; while sample sizes of 50 and above would further increase confidence levels. Sample sizes often exceeded 150 for some positions along the Snake River reach, but this extensive sampling probably did not enhance confidence levels compared to samples sizes ≥ 50 .

The first figure using this format (Figure 3.5.) compares the patterns of different life forms that were predicted by an extension of the Historical Operations (striped bars) versus the actual distribution in the field transects (black). As shown, the modeled values for year 40 are consistently and substantially higher than the vegetation patterns measured in the field. As we discussed before, this overestimation probably results from the lack of competition in the existing model. Consequently, vegetation is predicted to establish in all positions in which the hydrogeomorphic criteria are suitable.

The extent of over–estimation in the model’s predictions varies somewhat across life forms and elevations. As expected, the distributional extent of annuals is particularly inflated. This also applies to the facultative and obligate riparian annuals as well as the ruderal annuals. With competitive interactions, the annuals and especially the obligate riparian annuals and ruderal annuals would often be impeded from establishment in areas already occupied by other vegetation, either annual or perennial.

For the same reasons we suggest that the modeled and actual extent of the facultative riparian perennials becomes more closely aligned at higher elevations. These plants would be forced to compete with the other vegetation in the lower riparian zone. In the upper elevational zones, however, plants of this life form would compete only with other facultative riparian plants and upland species. The perennials would eventually become established whereas the annuals would continue to be impeded through competition, because of annual mode of seedling reestablishment for annual species.

We emphasize that model over-estimation should be recognized in the subsequent discussion of the modeling results. Although we consider that the projections are inflated, the extent of inflation should be consistent across the operational scenarios. Consequently, the model results are appropriate to quantitatively compare the ecological consequences of different operational scenarios.

This comparison of the modeled distribution with the actual extent also reveals a situation in which the model does not accurately predict plant distribution (Figure 3.5.). In the elevational zone from 2 to 1 m below the mean annual water level (-2 to -1 on horizontal axis), the model predicts substantial vegetation cover for most groups. However, this elevational zone was actually barren of vegetation, as determined from field studies.

3.6.1.3. Sampling Time-Step

The modeling sequence involved the progressive accumulation of perennial plants and the yearly establishment and growth of annual plants. Consequently, any single time-step that is selected as the end-point for the analysis would reflect the distribution of annuals for that particular year. To ensure that the patterns presented are typical of the modeled period, we generated model output at decade intervals. This provided a sequence of outputs from which we compared plant distribution patterns. For example, Figure 3.6. presents outputs for the final analysis after 100 years and for output after 40 years. As shown, the patterns of elevational distribution and relative abundances are very similar for the three groups of annual plants, the facultative riparian annuals, obligate riparian annuals and ruderal annuals. The outputs from the other decade time-steps were also similar for the different groupings of annual plants (data not presented). We therefore consider that patterns described are reflective of the typical patterns over the modeled time interval.

3.6.1.4. Sequence of Presentation and Interpretation

Modeling results are sequentially presented for each of the study reaches of the Hells Canyon Corridor. For each reach, an initial composite of six histograms represents the projected proportions and extent of the different vegetation groups with the two operational scenarios, the ROR) and proposed scenarios.

Subsequent histogram figures represent the aggregate outcome with the total proportion of modeled quadrats that would be vegetated by each plant group for related study reaches: (1) the three Brownlee Reservoir reaches, (2) the three lower reservoir reaches and (3) the Snake River below Hells Canyon Dam. These provide quantitative summaries for comparison across the two scenarios although these quantitative analyses represent relative vegetation extent and not

necessarily an abundance measure, such as vegetation cover within the quadrats. Recognizing the natural variation and imprecision in any modeling approach, only changes exceeding 10% of quadrats are discussed relative to the aggregate changes. A histogram summarizes both the elevational patterns (horizontal axis) and temporal patterns (vertical axis) for the vegetation groups across the two operational scenarios.

3.6.2. Modeling of Reservoir Shorelines

3.6.2.1. Brownlee Reservoir Reaches

The model predicts that the three Brownlee Reservoir reaches would probably display the greatest differences in vegetation patterns across the two operational scenarios. The three Brownlee Reservoir reaches provide a partial form of replication of the study results since all three experience similar water stage patterns. These collectively increase the number of sampled quadrats increasing the confidence in the common patterns relative to Brownlee Reservoir.

Brownlee Headwater

The partial draw-down of the Brownlee Reservoir under the proposed scenario would result in some colonization of the reservoir banks below the full-pool elevation. In contrast, under the ROR Scenario the reservoir would remain at full pool, eliminating the opportunity for colonization of the elevations below full-pool (Figure 3.7.).

Facultative Riparian Annuals

For most life forms, the principal differences between the ROR and proposed scenarios would involve some extension below full-pool under the proposed scenario (Figure 3.7). For facultative riparian annuals, predicted differences between the proposed and ROR scenarios are minimal with an anticipated downward extension of 0.5 to 1 m under the proposed scenario. This slight downward extension under the Proposed Scenario could produce a net increase of about 11% in the overall distribution of facultative riparian annuals in the proposed– versus ROR scenarios (Figure 3.8.).

Facultative Riparian Perennials

The model predicts a slight reduction in the extent of the facultative riparian perennials at the upper end of the riparian zone under the proposed scenario (Figure 3.7.). Thus, while the more dynamic draw-down under the proposed scenario favors downward extension of some vegetation groups, this is at the expense of a more reliable water level for facultative riparian perennials. However, the modeled increase in facultative riparian perennials at the 4 m elevation under the ROR Scenario may be questionable, because of smaller sample sizes. Recognizing this caution, the model predicts a 12% reduction in the facultative riparian perennials within the riparian zone under the proposed scenario.

Hydrophytes

The extension of vegetation below full pool would apply specifically to hydrophyte life forms (Figure 3.7.). Interestingly, the model predicts that the proposed scenario would produce

substantially more hydrophytes between 1.5 and 3 m below full-pool. Given their hydrophytic nature and widespread absence under current flow operations, we feel this model prediction does not adequately represent future distribution patterns of hydrophytes under the proposed scenario. Further, from 1 m below to 1 m above full pool, HC_REM predicts hydrophyte occurrence would be relatively similar between the two scenarios (Figure 3.8.). Given the nature and extent of seasonal draw-downs along Brownlee, we anticipate that hydrophytes would not increase under the proposed scenario. However, the range of hydrophytes could increase under the ROR Scenario. At this point, it appears additional model refinements (i.e., modification of life history features, potential influences of intra- and inter-specific competition) would be useful to adequately model the distribution of hydrophytes in this reach under either operational scenario.

Obligate Riparian Annuals

Similar to the facultative riparian annuals, the obligate riparian annual group is predicted to produce a slight downward extension with the proposed scenario (Figures 3.7. and 3.8.).

Obligate Riparian Perennials

The model predicts a slight downward extension of the obligate riparian perennials under the proposed scenario (Figure 3.7.). We were surprised that the model did not predict a reduction in this life form at the upper end of the riparian zone. However, limited sampling at the upper end diminishes our confidence in these model predictions. While the model predicts a 12% overall increase in the obligate riparian perennials (Figure 3.8.), we consider this increase to be an over-estimation due to incomplete information (i.e., limited sampling) at the upper end where a contrasting patterns might be expected.

Ruderal Annuals

The model predicts that this vegetation group will be the most affected vegetation group across the proposed– versus ROR scenarios (Figure 3.7.). With the reservoir draw-down of the proposed scenario, there will be extensive areas available for colonization by the weedy, ruderal annuals and the model predicts more than a 3-fold increase in this vegetation group (Figure 3.8.).

While the model predicts that most of the area between full pool and 10 m below this elevation would be available for colonization by ruderal annuals, we anticipate that the extent of cover would be relatively minimal, as is currently the case. Thus, the proportion of quadrats vegetated should not be equated with increased coverage per quadrat.. We consider that the predicted increase in ruderal annuals at an elevation of 3.5 to 4 m above full pool is not a reliable prediction and reflects limited sampling at that elevation. It is unlikely that there would be substantial differences in this life form at these high elevations between the proposed– and ROR scenarios.

Thus, in comparing the two operational scenarios, the most dramatic change would involve the downward extension of the ruderal annuals into the reservoir draw-down zone. There would also be slight downward extensions of other vegetation groups, particularly hydrophytes. The model predicts that the riparian and obligate perennials would undergo slight but contrasting patterns. We predict that there would be relatively little net change in the extent of shrubs and trees across the two operational scenarios.

Extent of Vegetation - Distribution versus Abundance

The model predicts the elevational distribution of vegetation groups, in addition to estimates of the proportions of the spatial units (quadrats) that would potentially support the vegetation group. However, the model does not incorporate competition and only predicts presence, not extent of cover within the quadrat.

The ROR Scenario would provide a nearly constant water elevation near the full pool level. Without the seasonal partial draw-down of the proposed scenario, the more constant water level under the ROR scenario may favor growth of vegetation near and above the full-pool elevation. This may be due to both the benefits of supplemental moisture for individual plants but perhaps more substantially; an increase in water availability will diminish one limiting resource for which adjacent plants compete. Therefore, we predict that a narrower but denser band of vegetation would occur near the full-pool elevation under the ROR Scenario. This assessment may be of particular significance for the hydrophytes. While both the proposed and ROR scenario are predicted to permit hydrophyte establishment in the zone from -1 to +1 m, these plants would be more vigorous with the constant water levels provided by the ROR Scenario. As a result of this interpretation, we hypothesize that the differences in vegetation cover abundances would probably be less than the predicted differences in extent.

The spatial and temporal differences predicted by the model for the proposed versus ROR scenario are summarized in Figure 3.9. Modeling was conducted over a period of 110 years (vertical axis). Plots located in the upper part of the graph indicate an earlier and more continuous establishment of vegetation during the model run.

Most of the vegetation groups are clustered close together suggesting a mean distribution near the full pool elevation while the extent of the horizontal bars reflect the elevational range of predicted distribution (Figure 3.9.). The mean values are also generally near the upper portion of the graph, indicating early establishment in the model run and continuous occurrence thereafter.

The ruderal annual position for the proposed scenario is situated below and to the left of the other symbols, indicating that these plants would be established in the draw-down zone (Figure 3.9.). These ruderal annuals would not be continuously present but instead would be intermittently established, when appropriate water regimes were provided. In contrast, the ROR Scenario would limit the distribution of the ruderal annuals to a narrow zone above full pool and hydrologic conditions in this zone would be favorable in most modeled years.

Under the proposed scenario, hydrophytes would probably neither be established across a broader range of elevations, nor thrive in the zone slightly below the full pool elevation (Figure 3.9.). Establishment at the lower elevations under the proposed scenario would be even less consistent as only some years would provide the hydrologic conditions for establishment and survival. Differences in the other life forms between the proposed- and ROR scenarios were similar to those of the ruderal annuals and hydrophytes but to a minor extent (Figure 3.9.).

Main Brownlee Reservoir

The greatest difference between the proposed- and ROR scenarios is with ruderal annuals (Figure 3.10.). These weedy species would be able to colonize the reservoir draw-down zone

under the proposed scenario. Thus, there would be a considerable downward extension of these plants; in fact the overall extent may double (Figure 3.8.).

The model predicts that there would be a minor downward extension of each of the five riparian life forms with similar expansions predicted for the facultative and obligate annuals and perennials (Figure 3.10.). The perennials would be slightly more restricted in lower distribution and occur at and above the full pool elevation, whereas the annuals would extend slightly below this elevation. The model predicts an 11% increase in the facultative riparian annuals and lesser impacts on the obligate riparian annuals and perennials (Figure 3.8.).

The model predicts a contrasting pattern at the upper end of the riparian zone, as the facultative riparian perennials decline in the upper zone under the proposed scenario (Figure 3.10.). This is predicted to be greater than the slight increase due to the downward extension. Consequently, the model predicts a 27% decrease in the facultative riparian perennials with the proposed scenario (Figure 3.8.). However, sampling was limited at the upper region of the riparian zone, reducing the confidence of this estimate.

As we noted earlier, hydrophytes would probably not be distributed as predicted in Figure 3.10. We also expect that hydrophytes at the higher elevation would be sparse in relation to the more dynamic water fluctuation of the proposed scenario; this would partially counter the increase in elevational extent. Additional work is needed to clarify the distribution of hydrophytes for this reach under both flow scenarios.

Thus, the greatest spatial and temporal differences in the vegetation with the proposed versus ROR scenario would involve the changes in the ruderal annual vegetation group (Figure 3.11.). The occurrence patterns of facultative riparian annuals would also differ somewhat, but other vegetation groups would experience minimal differences in distribution between the two operational scenarios.

Powder Arm of Brownlee Reservoir

The model predicts that the Powder River Arm would differ between the proposed and ROR scenarios. Some differences across the Brownlee reaches and the Powder Arm are more similar to the Brownlee Headwater reach than the Main Brownlee Reservoir reach (Figure 3.8.).

The greatest difference along the Powder Arm would be the extension of ruderal annuals into the draw-down zone under the proposed scenario (Figures 3.12. and 3.13.). The predicted 6-fold increase is greater than that predicted for the Brownlee Headwater reach (Figure 3.8.). We further predict that there would be a slight downward extension of some of the riparian vegetation groups (Figures 3.12. and 3.13.). Hydrophytes would extend downward about 2 m producing a net increase of about 63%, similar to that predicted for the Brownlee Headwater reach (Figure 3.8.). However, the more stable water level under the ROR scenario might increase hydrophyte abundance in a narrower zone and this might partially compensate for the increase width of the hydrophyte zone predicted for the proposed scenario. Consequently, the overall difference in abundance (cover) would probably be less than the predicted 63% increase in extent (distribution).

The model further predicts a slight downward extension of the facultative riparian annuals under the proposed scenario (Figures 3.12. and 3.13.). The model predicts a net increase of 21% (Figure 3.8.). However, the projections of the facultative riparian annuals may be overestimated due to competition among life forms near full pool. Consequently, the predicted increase appears to over-estimate differences between operational scenarios.

Thus, we predict that there may be a major increase along the Powder Arm in the extent of ruderal annuals due to the draw-down zone under the proposed scenario. Hydrophytes may slightly increase in the elevational extent, but this expansion should be countered by opposing changes in abundance under the proposed scenario.

3.6.2.2. Lower Reservoir Reaches

The second group of reservoir reaches includes the shorelines along Oxbow Reservoir, the Oxbow Bypass of Hells Canyon Reservoir and Hells Canyon Reservoir. Currently, these three reaches are relatively similar with respect to riparian vegetation and will experience generally similar hydrograph patterns under both the proposed and ROR scenario. Therefore, field sampling was less intensive along these reaches than along other study reaches.

Consistent with the limited differences in modeled hydrographs across the two scenarios, the HC_REM vegetation modeling predicts minor differences in vegetation under the proposed versus ROR scenarios for the three lower reservoir reaches. Generally similar patterns are predicted for each of these three reaches.

The model predicts a relatively narrow band of riparian vegetation extending from the full pool level up about 3 to 4 m in elevation (Figure 3.14.). This would retain the current plant distributions along the lower reservoir reaches, in which a fairly dense but narrow band of riparian vegetation creates an effect described as a ‘bathtub ring’ around the reservoir. We expect that interplant competition within this band is considerably. Consequently, we believe that the model projections are somewhat inflated, particularly for the facultative riparian annuals and the ruderal annuals that would be less competitive in this moist, low-elevational zone. As perennial vegetation persists in these narrow bands, opportunities for recruitment of annuals, which are ecological pioneers and often shade-intolerant, would be diminished.

Oxbow Reservoir

The model predicts a minor (12%) reduction in the facultative riparian annuals under the proposed scenario due to slightly less favorable conditions in the middle of the riparian zone (Figure 3.14.). Plant competition would particularly affect annual plants within this dense riparian zone. Facultative riparian perennials would extend slightly downwards under the proposed scenario, but this would be countered by less favorable conditions at the upper end of the riparian zone (Figure 3.14.). Overall, we predict minimal net change in this life form.

The model predicts little change in the hydrophytes and obligates riparian annuals for the two operational scenarios (Figure 3.14.). The obligate riparian perennials are predicted to increase by about 16% due to the downward extension slightly below full pool (Figures 3.14. and 3.15.).

The model predicts a slight downward extension of ruderal annuals with the proposed scenario but decreased occurrence from full pool up to about 2.5 m (Figure 3.14.). The ruderal annuals would not effectively compete with the perennial vegetation in the dense vegetation zone near full pool and consequently the 26% reduction in the proposed scenario is probably an adequate representation of future differences (Figure 3.15.).

We thus predict that along Oxbow Reservoir there would be a dense band of vegetation near full pool with both scenarios but the band would be slightly wider but less dense under the proposed scenario. We anticipate relatively minor net change between the two operational scenarios (Figure 3.16.).

Oxbow Bypass

The projected differences in vegetation groups along the Oxbow Bypass reach for the two scenarios are minor (Figure 3.17.). The model predicts a slight downward extension of some life forms, but such an extension would be modest at best and the model projects little net changes of any life form under the proposed— compared to the ROR scenario (Figure 3.15.). The model predicts that the hydrophytes would occur at lower elevations than the other vegetation groups clustered in a narrow band above full pool under either operational scenario (Figure 3.18.).

Hells Canyon Reservoir

The model predicts minimal difference in the distribution of riparian vegetation along the Hells Canyon Reservoir under the proposed compared to ROR scenarios (Figure 3.19.). The predicted differences in facultative riparian annual and perennials near the 3.5 to 4 m elevation may be an artifact due to limited sampling of upland habitats. Thus, although the model predicts modest overall changes in these groups (Figure 3.15.), we expect minimal differences between the two operational scenarios for each of the four riparian life forms.

The model predicted less favorable conditions for ruderal annuals under the proposed scenario (Figure 3.19.). However, this life form would be unlikely to thrive in the dense band of perennial vegetation situated slightly above full pool because ruderal annuals would be less competitive in this zone under either operational scenario. Thus, although the model predicts a 21% reduction in the overall distribution of ruderal annuals (Figure 3.15.), the ruderals constitute a minor vegetation component in the dense riparian vegetation zone. In summary, we predict only minimal differences in riparian vegetation between the two operational scenarios (Figure 3.20.).

3.6.3. Modeling of the Hells Canyon Reach of the Snake River

This study reach represents the flow-regulated reach along the Snake River downstream of the Hells Canyon Dam. This river riparian zone provides a distinctive and highly valued recreational landscape that is also especially rich in terms of wildlife habitat.

Both the current and projected riparian vegetation zones along the Snake River are somewhat different than the riparian zones along the reservoir shorelines. In terms of spatial pattern, the greatest difference involves the elevational extent of riparian vegetation. Obligate riparian vegetation extends up to about 10 m above the mean annual water level along the Snake River

but is limited to about 4 m above full pool along the reservoirs. This reflects the elevational dynamics of water surface as the river stage varies substantially within and across years. In contrast, the reservoir elevations have a defined upper limit imposed by the full pool/spillway elevation.

Overall, the model predicts that the differences across the two operational scenarios for the Snake River reach would be intermediate in magnitude between the substantial changes along the Brownlee Reservoir reaches and the slight differences along the lower reservoir reaches.

The modeled histograms of vegetation groups along the Snake River show two elevational zones that have anomalous peaks (Figure 3.21.). The lower peak occurs at -2 and -1.5 m while the upper peak occurs at 9.5 and 10 m. The predicted peak of vegetation at the lower elevation is probably a modeling artifact. This zone located below the mean annual water level is presently barren of vegetation and this pattern would probably continue with either the proposed or ROR scenarios. Thus, data associated with this modeled peak from -2 to -1 m were excluded from further consideration and were omitted from calculations of the overall changes in Figure 3.22. and Table 6.1.

Similarly, the modeled vegetation peaks at 9.5 and/or 10 m reflects an unusual occurrence of plants in particular study transects. These data are subsequently are over-represented in the analysis due to the limited number of study quadrats at those elevations. Observed riparian vegetation distributions display progressive change across the elevational profile with gradual reductions in most life forms towards the upper end of the study profile. As with the spurious lower peak, the data associated with the modeled upper peak were omitted from the calculations of summary statistics.

Facultative Riparian Annuals and Perennials

The facultative riparian plants typically occupy the highest elevational zone and might be expected to be less influenced by operational scenarios than the life forms growing in lower zones. The model output for the Snake River reach generally supports this prediction (Figure 3.21.).

Based on the modest hydrologic differences, the model predicts rather minimal differences in both the facultative riparian annuals and facultative riparian perennials under the proposed compared to the ROR scenario (Figure 3.21.). Across the elevational profile the model predicts minor changes at some elevations. There is little systematic change across the profile with some elevations being predicted to be elevated with the proposed scenario while other, sometimes adjacent elevations are predicted to be slightly decreased. These minor differences may represent random variation in the field data upon which the model was based. Overall, the model predicts minimal change in the facultative riparian annuals and perennials (0% and 2%, Figure 3.22.).

The model predicts that recruitment of the facultative riparian annuals (FRA) would occur at similar elevations but that such recruitment might be more frequent under the proposed than ROR scenarios (Figure 3.23.).

Hydrophytes

We question the predicted increase in the proportion of hydrophytes under proposed scenario (Figures 3.21. and 3.22.). Currently, hydrophytes have a limited distribution at higher elevations due to localized water retention from fine sediment ‘lenses’. Otherwise these plants are generally restricted to the zone from -0.5 to 2 m, relative to the mean annual water level (Figure 3.3.). We thus anticipate their distribution to remain sparse under the proposed scenario, with some moderate increases in abundance and distribution under the ROR scenario.

Obligate Riparian Annuals

The model predicts a slight increase in obligate riparian annuals under the proposed scenario due to slight increases in occurrence in the zone between 1.5 to 2.5 m (Figure 3.21.). However, the overall change in this vegetation group would be minimal (Figure 3.22.) in either overall distribution or establishment over the modeled period (Figure 3.23.). Further, the predicted increase in the obligate riparian annuals would occur in the densest zone of vegetation, where these annuals would compete with other plants, including both facultative and obligate riparian perennials.

Obligate Riparian Perennials

The obligate riparian perennials provide an especially important plant group relative to the provision of wildlife habitat. This group includes woody plants that provide shelter and forage for various large animals and willows that are also especially important habitats for insects and other invertebrates.

The model predicts a slight increase under the proposed scenario in the zone from 0.5 to 4 m above the mean annual water level (Figure 3.21.). Conversely, the model predicts slightly more favorable conditions for this vegetation group under the ROR scenario in the zone from -0.5 to 1 m. Minor differences at the upper end of the distribution are variable.

The model predicts a slight, 9% increase in overall distribution of the obligate riparian perennials under the proposed scenario (Figure 3.22.). However, in contrast to this calculation, the summary analysis of the elevation and temporal patterns for the obligate riparian perennials indicates rather minimal change in this vegetation group across the two operational scenarios (Figure 3.23.). Overall, the model predicts a slight increase in the obligate riparian perennials, particularly in the zone above the mean annual water level, with the proposed scenario.

Following construction of the Hells Canyon Complex, there were apparently similar changes in vegetation pattern (Blair et al. 2001). Following damming and flow regulation, the band of perennial riparian vegetation became slightly more dense and continuous along the reach. This represented a similar change to that predicted by the model for the proposed versus ROR scenarios.

Ruderal Annuals

The model predicts that the ruderal annuals would not substantially change under the two operational scenarios (Figure 3.21.). The overall extent of this life form (Figure 3.22.) and the spatial and temporal patterns would be very similar (Figure 3.23.).

3.7. Comparisons with Historic Operations

The Historic Operations pattern provides reservoir operations and river discharge patterns that are very similar to the proposed scenario. Consequently, all modeled vegetation patterns were also similar between the current management pattern and the proposed scenario.

In comparing the proposed and ROR scenarios, differences emerged among three groups of study reaches. The three Brownlee Reservoir reaches were predicted to experience the greatest differences in vegetation patterns related to seasonal reservoir draw-downs. The three lower reservoir reaches (Oxbow Reservoir, Oxbow Bypass and Hells Canyon Reservoir) would be exposed to similar operations under either the proposed– or ROR scenarios. Consequently, vegetation patterns were predicted to be very similar across the two operational scenarios. Finally, the Snake River reach downstream of Hells Canyon Dam would experience some difference in discharge and stream stage pattern and this would result in some slight differences in vegetation patterns between the proposed and ROR scenarios. Thus, the greatest differences in the prediction of plant distribution patterns occurred for the Brownlee Reservoir reaches, minimal differences would occur for the lower reservoir reaches, and the Snake River reach would also experience minimal differences across operational scenarios.

Following from this summarization, the comparisons of historic–, proposed–, and ROR scenarios is most appropriate for the Brownlee Reservoir reaches and for the Snake River reach below Hells Canyon Dam. We have analyzed all other comparisons and determined that, as expected, that there would be relatively minor differences along the lower reservoir reaches under either historic–, Proposed–, or ROR scenarios.

We have also determined that the patterns and relative differences between historic operations and either the proposed or ROR scenarios are very similar for each of the three Brownlee Reservoir reaches. Consequently, only a single comparison is presented, that for the Main reach of Brownlee Reservoir (Figure 3.24.). Similarly to the relative comparisons between the proposed and ROR scenarios, this reach of the Brownlee Reservoir was predicted to experience similar changes in vegetation pattern, but the Headwater reach was slightly more impacted than the Main reach of Brownlee Reservoir (Figure 3.8.).

For the Brownlee Reservoir reaches, Historic Operations would provide vegetation patterns that would be relatively similar to the proposed scenario (Figure 3.24.). The greatest difference across operational scenarios occurs for the ruderal annuals. For these life forms Historic Operations is slightly more favorable than the proposed scenario, while the reduced draw-down with the ROR Scenario would limit the extent of these annual plants. The model predicts that the proposed scenario would be marginally more favorable than the ROR Scenario for the obligate riparian annuals and perennials. Furthermore, the proposed scenario would be very similar to the Historic Operations relative to these important life forms. Hydrophytes would be limited under all operational scenarios and the model predicts similar patterns with proposed– and historic operations. The facultative riparian perennials provide a slight difference from the otherwise consistent pattern in which the proposed scenario would be similar to historic operations and these two would be slightly or substantially (ruderal annuals) different from the ROR scenario (Figure 3.24.).

As discussed in prior sections, the model predicts minimal differences across operational scenarios for the Snake River downstream of Hells Canyon Dam (Figures 3.22. and 3.23.). The same conclusion applies in the comparison with Historic Operations (Figure 3.24.). The model thus predicts minimal differences for the downstream riverine reach under the three Scenarios. Current predictions for the expansion of hydrophytes warrant further analysis (Figure 3.24.).

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Table 3.1.A. Common species surveyed per vegetation group along the Brownlee Reservoir – Headwater (BH).

| Vegetation Group | Species | # Quadrats | Scientific Name | Common Name |
|------------------|---------|------------|---|-------------------------------|
| (FRA) | MOVE | 12 | <i>Mollugo verticillata</i> | carpetweed |
| Facultative | MEOF | 4 | <i>Melilotus officinalis</i> | yellow sweetclover |
| Riparian | HEAN | 2 | <i>Helianthus annuus</i> | common sunflower |
| Annuals | POAV | 2 | <i>Polygonum aviculare</i> | prostrate knotweed |
| (FRP) | LELA | 19 | <i>Lepidium latifolium</i> | perennial pepperweed |
| Facultative | ACSA | 6 | <i>Acer saccharinum</i> | silver maple |
| Riparian | ACSA5 | 5 | <i>Acer saccharinum</i> (seedling) | silver maple (seedling) |
| Perennials | APAN | 5 | <i>Apocynum androsaemifolia</i> | spreading dogbane |
| | CHVI | 3 | <i>Chrysopsis villosa hispida</i> | hairy golden aster |
| | APCA | 2 | <i>Apocynum cannabinum</i> | hemp dogbane |
| | ALRH | 1 | <i>Alnus rhombifolia</i> | white alder |
| | ALRH5 | 1 | <i>Alnus rhombifolia</i> (seedling) | white alder (seedling) |
| | ARLU | 1 | <i>Artemisia ludoviciana / A. linleyana</i> | Western mugwort |
| | ELAN | 1 | <i>Elaeagnus angustifolia</i> | Russian olive |
| | PLMA | 1 | <i>Plantago major</i> | broadleaf plantain |
| | RUCR | 1 | <i>Rumex crispus</i> | curly dock |
| | SODU | 1 | <i>Solanum dulcamara</i> | bittersweet nightshade |
| | TAVU | 1 | <i>Tanacetum vulgare</i> | common tansy |
| (HYD) | IRPS | 1 | <i>Iris pseudoacorus</i> | yellow iris / yellow-flag |
| Hydrophytes | SCAC | 1 | <i>Scirpus acutus</i> | common bulrush |
| (ORA) | HEAL | 38 | <i>Heleochloa alopecuroides</i> | heleochloa |
| Obligate | POPE | 20 | <i>Polygonum persicaria</i> | spotted ladythumb |
| Annuals | EUGL | 2 | <i>Euphorbia glyptosperma</i> | corrgate-seeded spurge |
| (ORP) | TARA | 43 | <i>Tamarix ramosissima+parviflora</i> | salt cedar complex |
| Obligate | SAEX | 35 | <i>Salix exigua</i> | coyote/sandbar willow |
| Riparian | SAAL | 27 | <i>Salix alba</i> | European white willow |
| Perennials | CYES | 24 | <i>Cyperus esculentus</i> | yellow nut sedge |
| | SALA | 23 | <i>Salix lasiandra</i> | Pacific willow |
| | PODE | 16 | <i>Populus deltoides</i> | Plains cottonwood |
| | AMFR | 13 | <i>Amorpha fruticosa</i> | false indigo |
| | LYSA | 12 | <i>Lythrum salicaria</i> | purple loosestrife |
| | PHAR | 8 | <i>Phalaris arundinacea</i> | reed canarygrass |
| | CYAR | 6 | <i>Cyperus aristatus</i> | short-pointed flatsedge |
| | TARA5 | 6 | <i>Tamarix</i> (seedling) | salt cedar complex (seedling) |
| | SALX5 | 5 | <i>Salix</i> spp. (seedling) | willow species (seedling) |
| | POP5 | 2 | <i>Populus</i> spp. (seedling) | poplar species (seedling) |
| | CYER | 2 | <i>Cyperus erthyrorhizos</i> | red-rooted flatsedge |
| | AMFR5 | 1 | <i>Amorpha fruticosa</i> (seedling) | false indigo (seedling) |
| | ELEO | 1 | <i>Eleocharis</i> spp. | spike rush |
| (RA) | XAST | 179 | <i>Xanthium strumarium</i> | common cocklebur |
| Ruderal | POOL | 101 | <i>Portulaca oleracea</i> | purselane |
| Annuals | AMAL | 64 | <i>Amaranthus albus</i> | tumble pigweed |
| | AMRE | 54 | <i>Amaranthus retroflexus</i> | redroot pigweed |
| | ECCR | 37 | <i>Echinochola crus-galli</i> | barnyard grass |
| | TRTE | 35 | <i>Tribulis terrestris</i> | puncture vine |
| | PACA | 33 | <i>Panicum capillare</i> | common witchgrass |
| | POAN | 29 | <i>Poa annua</i> | annual bluegrass |
| | CHMU | 28 | <i>Chenopodium murale</i> | nettleleaf goosefoot |
| | POLA | 20 | <i>Polygonum lapathifolium</i> | pale smartweed |
| | COCA | 7 | <i>Conyza Canadensis</i> | horseweed |
| | EPPA | 4 | <i>Epilobium paniculatum</i> | autumn willow-herb |
| | DISA | 2 | <i>Digitaria sanguinalis</i> | large crabgrass |
| | SAIB | 2 | <i>Salsola iberica</i> | Russian thistle |
| | FEOC | 1 | <i>Festuca octoflora</i> | six-weeks fescue |
| | GAPA | 1 | <i>Gaura parviflora</i> | velvety gaura |

Table 3.1.B. Common species surveyed per vegetation group along the Brownlee Reservoir - Main (BM).

| Vegetation Group | Species | # Quadrats | Scientific Name | Common Name |
|---------------------------------|---------|------------|-------------------------------------|------------------------------------|
| (FRA) | | | | |
| Facultative | MEOF | 24 | <i>Meliolotus officinalis</i> | yellow sweetclover |
| Riparian | HEAN | 16 | <i>Helianthus annuus</i> | common sunflower |
| Annuals | POAV | 2 | <i>Polygonum aviculare</i> | prostrate knotweed |
| (FRP) | | | | |
| Facultative | LELA | 19 | <i>Lepidium latifolium</i> | perennial pepperweed |
| Riparian | CERE | 11 | <i>Celtis reticulata</i> | netleaf hackberry |
| Perennials | ASSP | 6 | <i>Asclepias speciosa</i> | showy milkweed |
| | NECA | 4 | <i>Nepeta cataria</i> | catnip |
| | CHVI | 2 | <i>Chrysopsis villosa hispida</i> | hairy golden aster |
| | TORA | 2 | <i>Toxicodendron radicans</i> | poison-ivy |
| | ULPA | 2 | <i>Ulmus parvifolia / U. pumila</i> | Chinese elm (and Siberian elm) |
| | APCA | 1 | <i>Apocynum cannabinum</i> | hemp Dogbane |
| | CERE5 | 1 | <i>Celtis reticulata (seedling)</i> | netleaf hackberry (seedling) |
| | ELAN | 1 | <i>Elaeagnus angustifolia</i> | Russian-olive |
| | RUCR | 1 | <i>Rumex crispus</i> | curly dock |
| (HYD) | | | | |
| Hydrophytes | POAM | 1 | <i>Polygonum amphibium</i> | Water smartweed |
| (ORA) | | | | |
| Obligate Riparian Annuals | EUGL | 11 | <i>Euphorbia glyptosperma</i> | corrugate-seeded spurge |
| (ORP) | | | | |
| Obligate | AMFR | 27 | <i>Amorpha fruticosa</i> | false indigo |
| Riparian | SAEX | 25 | <i>Salix exigua</i> | coyote/sandbar willow |
| Perennials | CYES | 2 | <i>Cyperus esculentus</i> | yellow nut sedge |
| | PHAR | 2 | <i>Phalaris arundinacea</i> | reed canarygrass |
| (RA) | | | | |
| Ruderal | XAST | 202 | <i>Xanthium strumarium</i> | common cocklebur |
| Annuals | POOL | 198 | <i>Portulaca oleracea</i> | purselane |
| | AMAL | 173 | <i>Amaranthus albus</i> | tumble pigweed |
| | AMRE | 49 | <i>Amaranthus retroflexus</i> | redroot pigweed |
| | ECCR | 23 | <i>Echinochola crus-galli</i> | barnyard grass |
| | TRTE | 17 | <i>Tribulis terrestris</i> | puncture vine |
| | EPPA | 14 | <i>Epilobium paniculatum</i> | autumn willow-herb |
| | POAN | 13 | <i>Poa annua</i> | annual bluegrass |
| | LEPE | 7 | <i>Lepidium perfoliatum</i> | clasping pepperweed |
| | VUMY | 5 | <i>Vulpia myuros</i> | rattail fescue |
| | ATRO | 3 | <i>Atriplex rosea</i> | red orache |
| | COCA | 3 | <i>Conyza canadensis</i> | horseweed |
| | POER | 3 | <i>Polygonum erectum</i> | erect knotweed |
| | AMPA | 2 | <i>Amaranthus palmeri</i> | Palmer amaranth / carelessnessweed |
| | EPMI | 2 | <i>Epilobium minutum</i> | small-flowered willow-herb |
| | POLA | 2 | <i>Polygonum lapathifolium</i> | pale smartweed |
| | AMAR | 1 | <i>Ambrosia artemisiifolia</i> | common ragweed |
| | DISA | 1 | <i>Digitaria sanguinalis</i> | large crabgrass |
| | GAPA | 1 | <i>Gaura parviflora</i> | velvety gaura |

Table 3.1.C. Common species surveyed per vegetation group along the Brownlee Reservoir - Powder River Arm (BP).

| Vegetation Group | Species | # Quadrats | Scientific Name | Common Name |
|------------------|---------|------------|--------------------------------|------------------------|
| (FRA) | | | | |
| Facultative | POAV | 3 | <i>Polygonum aviculare</i> | prostrate knotweed |
| Riparian | MEOF | 1 | <i>Melilotus officinalis</i> | yellow sweetclover |
| Annuals | | | | |
| (FRP) | | | | |
| Facultative | RUCR | 2 | <i>Rumex crispus</i> | curly dock |
| Riparian | ASSP | 1 | <i>Asclepias speciosa</i> | showy milkweed |
| Perennials | PLMA | 1 | <i>Plantago major</i> | broadleaf plantain |
| (HYD) | | | | |
| Hydrophytes | POAM | 22 | <i>Polygonum amphibium</i> | Water smartweed |
| (ORA) | | | | |
| Obligate | EUGL | 5 | <i>Euphorbia glyptosperma</i> | corrgate-seeded spurge |
| Riparian | | | | |
| Annuals | | | | |
| (ORP) | | | | |
| Obligate | SAEX | 15 | <i>Salix exigua</i> | coyote/sandbar willow |
| Riparian | PHAR | 11 | <i>Phalaris arundinacea</i> | reed canarygrass |
| Perennials | SALA | 4 | <i>Salix lasiandra</i> | Pacific willow |
| (RA) | | | | |
| Ruderal | POOL | 116 | <i>Portulaca oleracea</i> | purselane |
| Annuals | POAN | 95 | <i>Poa annua</i> | annual bluegrass |
| | XAST | 43 | <i>Xanthium strumarium</i> | common cocklebur |
| | PACA | 31 | <i>Panicum capillare</i> | common witchgrass |
| | ECCR | 30 | <i>Echinochola crus-galli</i> | barnyard grass |
| | AMAL | 21 | <i>Amaranthus albus</i> | tumble pigweed |
| | AMRE | 16 | <i>Amaranthus retroflexus</i> | redroot pigweed |
| | CHBE | 4 | <i>Chenopodium berlandieri</i> | netseed lambsquarters |
| | COCA | 4 | <i>Conyza canadensis</i> | horseweed |

Table 3.1.D. Common species surveyed per vegetation group along the Oxbow Reservoir - Main (OM).

| Vegetation Group | Species | # Quadrats | Scientific Name | Common Name |
|------------------|---------|------------|---|--------------------------------|
| (FRA) | | | | |
| Facultative | MEOF | 10 | <i>Meliolotus officinalis</i> | yellow sweetclover |
| Riparian | HEAN | 7 | <i>Helianthus annuus</i> | common sunflower |
| Annuals | POAV | 3 | <i>Polygonum aviculare</i> | prostrate knotweed |
| (FRP) | | | | |
| Facultative | LELA | 19 | <i>Lepidium latifolium</i> | perennial pepperweed |
| Riparian | CERE | 14 | <i>Celtis reticulata</i> | netleaf hackberry |
| Perennials | TORA | 13 | <i>Toxicodendron radicans</i> | poison-ivy |
| | ARLU | 11 | <i>Artemisia ludoviciana / A. linleyana</i> | Western mugwort |
| | ASSP | 6 | <i>Asclepias speciosa</i> | showy milkweed |
| | RUDI | 6 | <i>Rubus discolor</i> | Himalayan blackberry |
| | AGUR | 4 | <i>Agastache urticifolia</i> | horse mint |
| | COMA | 4 | <i>Conium maculatum</i> | poison hemlock |
| | ELAN | 3 | <i>Elaeagnus angustifolia</i> | Russian-olive |
| | RUCR | 2 | <i>Rumex crispus</i> | curly dock |
| | EPGL | 1 | <i>Epilobium glaberrimum</i> | smooth willow-herb |
| | FRPE | 1 | <i>Fraxinus pennsylvanica</i> | ash |
| | NECA | 1 | <i>Nepeta cataria</i> | catnip |
| | PHLO | 1 | <i>Physalis longifolia</i> | long-leaved ground cherry |
| | PLMA | 1 | <i>Plantago major</i> | broadleaf plantain |
| | ULAM | 1 | <i>Ulmus americana</i> | American elm |
| | ULPA | 1 | <i>Ulmus parvifolia / U. pumila</i> | Chinese elm (and Siberian elm) |
| (HYD) | | | | |
| Hydrophytes | IRPS | 16 | <i>Iris pseudoacorus</i> | yellow iris / yellow-flag |
| (ORP) | | | | |
| Obligate | AMFR | 18 | <i>Amorpha fruticosa</i> | false indigo |
| Riparian | SAEX | 15 | <i>Salix exigua</i> | coyote/sandbar willow |
| Perennials | EQLA | 13 | <i>Equisetum laevigatum</i> | smooth scouring-rush |
| | CAVU | 5 | <i>Carex vulpinoidea</i> | fox sedge |
| | CYER | 2 | <i>Cyperus erthyrorhizos</i> | red-rooted flatsedge |
| | LYAM | 2 | <i>Lycopus americanus</i> | cut-leaved water horehound |
| | CIDO | 1 | <i>Cicuta douglasii</i> | water hemlock |
| (RA) | | | | |
| Ruderal | EPPA | 8 | <i>Epilobium paniculatum</i> | autumn willow-herb |
| Annuals | AMAL | 3 | <i>Amaranthus albus</i> | tumble pigweed |
| | AMAR | 2 | <i>Ambrosia artemisiifolia</i> | common ragweed |
| | COCA | 2 | <i>Conyza canadensis</i> | horseweed |
| | GAPA | 1 | <i>Gaura parviflora</i> | velvety gaura |

Table 3.1.E. Common species surveyed per vegetation group along the Hells Canyon Reservoir - Oxbow Bypass (OB).

| Vegetation Group | Species | # Quadrats | Scientific Name | Common Name |
|------------------|---------|------------|---|------------------------------|
| (FRA) | | | | |
| Facultative | HEAN | 1 | <i>Helianthus annuus</i> | common sunflower |
| Riparian | MEOF | 1 | <i>Melilotus officinalis</i> | yellow sweetclover |
| Annuals | | | | |
| (FRP) | | | | |
| Facultative | ARLU | 11 | <i>Artemisia ludoviciana / A. linleyana</i> | Western mugwort |
| Facultative | PHLO | 9 | <i>Physalis longifolia</i> | long-leaved ground cherry |
| Riparian | LELA | 4 | <i>Lepidium latifolium</i> | perennial pepperweed |
| Perennials | CERE | 3 | <i>Celtis reticulata</i> | netleaf hackberry |
| | PLMA | 2 | <i>Plantago major</i> | broadleaf plantain |
| | TORA | 2 | <i>Toxicodendron radicans</i> | poison-ivy |
| | APAN | 1 | <i>Apocynum androsaemifolia</i> | spreading dogbane |
| | ASSP | 1 | <i>Asclepias speciosa</i> | showy milkweed |
| | CERES | 1 | <i>Celtis reticulata</i> (seedling) | netleaf hackberry (seedling) |
| | PADI | 1 | <i>Paspalum distichum</i> | knotgrass |
| (ORA) | | | | |
| Obligate | EUGL | 11 | <i>Euphorbia glyptosperma</i> | corrgate-seeded spurge |
| Riparian | | | | |
| Annuals | | | | |
| (ORP) | | | | |
| Obligate | SAEX | 4 | <i>Salix exigua</i> | coyote/sandbar willow |
| Obligate | AMFR | 3 | <i>Amorpha fruticosa</i> | false indigo |
| Riparian | AMFR5 | 3 | <i>Amorpha fruticosa</i> (seedling) | false indigo (seedling) |
| Perennials | CYAR | 1 | <i>Cyperus aristatus</i> | short-pointed flatsedge |
| | SALX5 | 1 | <i>Salix</i> spp. (seedling) | willow species (seedling) |
| (RA) | | | | |
| Ruderal | XAST | 14 | <i>Xanthium strumarium</i> | common cocklebur |
| | AMAL | 2 | <i>Amaranthus albus</i> | tumble pigweed |
| Annuals | COCA | 2 | <i>Conyza canadensis</i> | horseweed |
| | ECCR | 2 | <i>Echinochola crus-galli</i> | barnyard grass |
| | PACA | 2 | <i>Panicum capillare</i> | common witchgrass |
| | POOL | 2 | <i>Portulaca oleracea</i> | puselane |
| | SEGL | 2 | <i>Setaria glauca</i> | yellow foxtail grass |
| | AMAR | 1 | <i>Ambrosia artemisiifolia</i> | common ragweed |
| | POAN | 1 | <i>Poa annua</i> | annual bluegrass |
| | SEVI | 1 | <i>Setaria viridis</i> | green bristlegrass |

Table 3.1.F. Common species surveyed per vegetation group along the Hells Canyon Reservoir - Main (HM).

| Vegetation Group | Species | # Quadrats | Scientific Name | Common Name |
|------------------|---------|------------|---|------------------------------------|
| (FRA) | | | | |
| Facultative | MEOF | 6 | <i>Melilotus officinalis</i> | yellow sweetclover |
| Riparian | HEAN | 2 | <i>Helianthus annuus</i> | common sunflower |
| Annuals | POAV | 1 | <i>Polygonum aviculare</i> | prostrate knotweed |
| (FRP) | | | | |
| Facultative | CERE | 23 | <i>Celtis reticulata</i> | netleaf hackberry |
| Riparian | RUDI | 16 | <i>Rubus discolor</i> | Himalayan blackberry |
| Perennials | TORA | 13 | <i>Toxicodendron radicans</i> | poison-ivy |
| | LELA | 8 | <i>Lepidium latifolium</i> | perennial pepperweed |
| | ULAM | 6 | <i>Ulmus americana</i> | American elm |
| | ASSP | 4 | <i>Asclepius speciosa</i> | showy milkweed |
| | PHLE | 4 | <i>Philadelphus lewisii</i> | Syringa / mock orange |
| | HOLA | 3 | <i>Holcus lanatus</i> | common velvet-grass |
| | PHLO | 3 | <i>Physalis longifolia</i> | long-leaved ground cherry |
| | AGUR | 2 | <i>Agastache urticifolia</i> | horse mint |
| | ARLU | 2 | <i>Artemesia ludoviciana / A. linleyana</i> | Western mugwort |
| | RHPU | 2 | <i>Rhamnus purshiana</i> | casacara |
| | COMA | 1 | <i>Conium maculatum</i> | poison hemlock |
| | COST | 1 | <i>Cornus stolonifera</i> | red-osier dogwood |
| | RUCR | 1 | <i>Rumex crispus</i> | curly dock |
| | SARA | 1 | <i>Sambucus racimosa</i> | black elderberry |
| (HYD) | | | | |
| Hydrophytes | IRPS | 1 | <i>Iris pseudoacorus</i> | yellow iris / yellow-flag |
| (ORP) | | | | |
| Obligate | AMFR | 18 | <i>Amorpha fruticosa</i> | false indigo |
| Riparian | PHAR | 4 | <i>Phalaris arundinacea</i> | reed canarygrass |
| Perennials | CIDO | 1 | <i>Cicuta douglasii</i> | water hemlock |
| (RA) | | | | |
| Ruderal | EPPA | 9 | <i>Epilobium paniculatum</i> | autumn willow-herb |
| Annuals | FEOC | 4 | <i>Festuca octoflora</i> | six-weeks fescue |
| | AMPA | 3 | <i>Amaranthus palmeri</i> | Palmer amaranth / carelessnessweed |
| | EUSE | 3 | <i>Euphorbia serpyllifolia</i> | thyme-leaved spurge |
| | AMAL | 2 | <i>Amaranthus albus</i> | tumble pigweed |
| | AMAR | 2 | <i>Ambrosia artemisiifolia</i> | common ragweed |
| | GAPA | 1 | <i>Gaura parviflora</i> | velvety gaura |
| | XAST | 1 | <i>Xanthium strumarium</i> | common cocklebur |

Table 3.1.G. Common species surveyed per vegetation group along the Snake River (SN).

| Vegetation Group | Species | # Quadrats | Scientific Name | Common Name |
|------------------|---------|------------|---|--------------------------------|
| (FRA) | MEOF | 192 | <i>Meliolotus officinalis</i> | yellow sweetclover |
| Facultative | HEAN | 44 | <i>Helianthus annuus</i> | common sunflower |
| Riparian | ERCI | 26 | <i>Eragrostis cilianensis</i> | Stinkgrass |
| Annuals | MOVE | 6 | <i>Mollugo verticillata</i> | carpetweed |
| (FRP) | CERE | 318 | <i>Celtis reticulata</i> | netleaf hackberry |
| Facultative | PHLO | 178 | <i>Physalis longifolia</i> | long-leaved ground cherry |
| Riparian | ARLU | 158 | <i>Artemisia ludoviciana / A. linleyana</i> | Western mugwort |
| Perennials | GLLE | 93 | <i>Glycyrrhiza lepidota</i> | American licorice |
| | ARLI | 71 | <i>Artemisia lindleyana</i> | Columbia R. mugwort |
| | TORA | 65 | <i>Toxicodendron radicans</i> | poison-ivy |
| | CERE5 | 53 | <i>Celtis reticulata</i> (seedling) | netleaf hackberry (seedling) |
| | ASEA | 40 | <i>Aster eatonii</i> | Easton's aster |
| | CYSC | 23 | <i>Cyperus schweinitzii</i> | Schweinitz flatsedge |
| | CHVI | 22 | <i>Chrysopsis villosa hispida</i> | hairy golden aster |
| | ASSP | 17 | <i>Asclepias speciosa</i> | showy milkweed |
| | APAN | 14 | <i>Apocynum androsaemifolia</i> | spreading dogbane |
| | APCA | 11 | <i>Apocynum cannabinum</i> | hemp Dogbane |
| | ALRH | 6 | <i>Alnus rhombifolia</i> | white alder |
| | PHLE | 6 | <i>Philadelphus lewisii</i> | Syringa / mock orange |
| | PRVI | 5 | <i>Prunus virginiana</i> | chokecherry |
| | ASFR | 4 | <i>Asclepias fascicularis</i> | narrow-ldv milkweed |
| | COMA | 4 | <i>Conium maculatum</i> | poison hemlock |
| | RUCR | 4 | <i>Rumex crispus</i> | curly dock |
| | COST | 1 | <i>Cornus stolonifera</i> | red-osier dogwood |
| | HEAU | 1 | <i>Helenium autumnale</i> | mountain sneeze weed |
| | TORA5 | 1 | <i>Toxicodendron radicans</i> (seedling) | poison-ivy (seedling) |
| (HYD) | POAM | 42 | <i>Polygonum amphibium</i> | Water smartweed |
| Hydrophytes | POCO | 1 | <i>Polygonum coccineum</i> | Water smartweed |
| (ORA) | | | | |
| Obligate | EUGL | 160 | <i>Euphorbia glyptosperma</i> | corrgate-seeded spurge |
| Riparian | POMO | 5 | <i>Polypogon monspeliensis</i> | rabbit foot polypogon |
| Annuals | | | | |
| (ORP) | SAEX | 58 | <i>Salix exigua</i> | coyote/sandbar willow |
| Obligate | EQLA | 44 | <i>Equisetum laevigatum</i> | smooth scouring-rush |
| Riparian | SPPE | 12 | <i>Spartina pectinata</i> | Prairie cordgrass |
| Perennials | CAVU | 6 | <i>Carex vulpinoidea</i> | fox sedge |
| | SALX5 | 3 | <i>Salix</i> spp. (seedling) | willow species (seedling) |
| | POTR | 3 | <i>Populus trichocarpa</i> | black cottonwood |
| | PHAR | 1 | <i>Phalaris arundinacea</i> | reed canarygrass |
| (RA) | PACA | 191 | <i>Panicum capillare</i> | common witchgrass |
| Ruderal | XAST | 70 | <i>Xanthium strumarium</i> | common cocklebur |
| Annuals | CELO | 33 | <i>Cenchrus longispinus</i> | Sandbur |
| | COCA | 20 | <i>Conyza canadensis</i> | horseweed |
| | AMAR | 17 | <i>Ambrosia artemisiifolia</i> | common ragweed |
| | AMPA | 13 | <i>Amaranthus palmeri</i> | Palmer amaranth / carelessweed |
| | SEVI | 13 | <i>Setaria viridis</i> | green bristlegrass |
| | POOL | 11 | <i>Portulaca oleracea</i> | purselane |
| | AMAL | 8 | <i>Amaranthus albus</i> | tumble pigweed |
| | GAPA | 7 | <i>Gaura parviflora</i> | velvety gaura |
| | EUSE | 6 | <i>Euphorbia serpyllifolia</i> | thyme-leaved spurge |
| | AMRE | 5 | <i>Amaranthus retroflexus</i> | redroot pigweed |
| | CESO | 3 | <i>Centaurea solstitialis</i> | yellow star thistle |
| | VUMY | 3 | <i>Vulpia myuros</i> | rattail fescue |
| | EPPA | 2 | <i>Epilobium paniculatum</i> | autumn willow-herb |
| | POER | 2 | <i>Polygonum erectum</i> | erect knotweed |
| | ECCR | 1 | <i>Echinochola crus-galli</i> | barnyard grass |
| | PLPA | 1 | <i>Plantago patagonica</i> | wooly plantain |
| | TRTE | 1 | <i>Tribulis terrestris</i> | puncture vine |

Table 3.2. Autecology of select plant species along the Hells Canyon Complex of reservoirs (bold type indicates key species and * indicates NOX / TES). Abbreviations for all species are defined in Appendix 3-1.

| Species | Annual Biennial Perennial | Seedling vs Clonal Reproduction | Flowering Period | Seed-Dispersal Period | Seed-Dispersal Agent | Seed-Germination Period | Seed-Viability Period | Reference |
|---------|---------------------------|---------------------------------|------------------|-----------------------|----------------------|-------------------------|-----------------------|-------------|
| ACSA | W | S | Feb-May | Apr-Jun | wind, water | May-Jun | < 1 yr | 10, 25 |
| AGSP | P | S / C | spring | May-Jun | (wind) | early spring | > 2 yrs | 23 |
| ALRH | W | S / C | Mar | Sep-Feb | wind, water | spring | (< 1 yr) | 31 |
| AMAL | A | S | Jul-Oct | Sep-Oct | wind | year-round | 2 yrs | 39 |
| AMFR | W | C / S | May-Jun | autumn | water | spring | < 2 yrs | 4 |
| AMRE | A | S | Jul-Oct | Aug-Oct | wind | year-round | 150 yrs | 9, 42 |
| ANMI | P | S / C | May-Jul | Aug-Sep | wind | spring | < 1 yr | 16 |
| ARLI | P | S / C | Aug-Sep | Aug-Sep | wind | spring | (2-3 yrs) | 18, 23 |
| BRJA | A | S | May-Jun | Sep-Oct | wind, animal | autumn | > 2 yrs | 13 |
| BRTE | A / B | S | Apr-May | Jun-Jul | wind, animal | Aug-Sep | 2-5 yrs | 35 |
| CADR | P | C / S | Jun-Sep | Jul-Sep | wind | (spring) | < 2 yrs | 19 |
| CERE | W | S / C | Apr-May | Aug-Sep | animal | spring | > 2 yrs | 29 |
| CHVI | P | S | Jul-Aug | Sep-Oct | wind | Mar-Jun | | 3, 23 |
| COAR * | P | C / S | Jun-Oct | Jul-Oct | animal, water | | 50 yrs | 39 |
| CYES* | P | C / S | summer | autumn | | May-Jul | 7-8 yrs | 45,39,46,47 |
| CYSC * | P | C / S | | | | | | |
| DISY | B | S | Jul-Sep | Sep-Oct | wind, water | Apr-Jun | > 5 yrs | 38 |
| ECCR | A | S | Aug | Aug-Sep | animal, water | Jun-Aug | > 8 yrs | 17 |
| ELAN | W | S / C | May-Jun | Aug-Nov | animal | spring | < 3 yrs | 26 |
| EQAR * | P | C/Spore | spring | spring | wind | summer | | 39 |
| GLLE | P | C / S | Jul-Aug | Sep-Oct | animal | (spring) | | 7 |
| GRSQ | P/B | S | Jul-Aug | Aug-Sep | wind | spring | | 23, 37 |
| HEAN | A | S | Jul-Sep | Sep-Oct | animal | spring | < 3 yrs | 39, 42 |
| | | | | | wind, water, | | | |
| HYPE | P | S / C | Jun-Aug | Aug-Sep | animal | spring | > 3 yrs | 5, 23 |
| LASE | B / A | S | Jul-Sep | Aug-Oct | wind | fall/spring | | 39 |
| LELA | P | C / S | Jun-Aug | Aug-Oct | wind | year-round | > 1 yr | 8 |
| LYSA | P | S / C | Jun-Aug | Jul-Sep | water, animal | May-Jun | > 1 yr | 33 |
| MEOF | A / B | S | May-Jul | Jul-Sep | wind, water | year-round | >20 yrs | 24, 30 |
| ONAC * | B | S | Jul-Sep | Aug-Oct | wind | (fall/spring) | | 40 |
| PACA | A | S | Jul-Sep | Aug-Oct | wind | May-Jun | (>2 yrs) | 39,43,44 |
| PHAR | P | C / S | Jun-Jul | Jul-Aug | wind | Aug-Sep | < 1 yr | 21 |
| POAM | P | C / S | sum-fall | fall | water | summer | (1-2 yrs) | 22 |
| POLA | A | S | sum-fall | fall | water, animal | Apr-May | 5 yrs | 12, 22 |
| POAN | A | S | Mar-Aug | Jul-Oct | wind, animal | Aug-Sep | 5 yrs | 12, 39 |
| POOL | A | S | Jul-Sep | Jul-Sep | wind | year-round | > 5 yrs | 39 |
| POSE | P | S / C | May-Jun | Jun-Jul | wind | (spring) | | 14 |
| POTR | W | S / C | Mar-Apr | May-Jun | wind, water | May-Jun | < 1 yr | 15 |
| RUDI | W | C / S | Jun-Aug | Aug-Sep | animal | (spring) | > 2 yrs | 28 |
| SAEX | W | C / S | early spr. | May-Jun | wind | spring | < 1 yr | 32 |
| SPCR | P | S / C | Jun-Jul | Jul-Aug | wind | (spring) | > 20 yrs | 2 |
| TACA | A | S | May-Jun | Jun-Jul | wind, animal | Oct-Nov | 1-2 yrs | 1 |
| TASP | W | S | Mar-Sep | Apr-Oct | wind, water | year-round | < 1 yr | 27 |
| TORA | W | S / C | May-Jul | Aug-Nov | animal, water | (spring) | | 20, 27 |
| TRTE * | A | S | summer | Jul-Oct | animal | May-Jun | 4-5 yr | 41, 39 |
| ULPU | W | S / C | Apr-May | May-Jun | wind, water | (fall/spring) | 1 yr | 15 |
| VEBL | B | S | Jun-Sep | Aug-Sep | wind | early spring | >90 yrs | 6, 11 |
| XAST | A | S | Aug | Aug-Sep | water, animal | Apr-Jul | 1-2 yrs | 34 |

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Table 3.3. Comparison of elevational range (m, relative to full pool level) of life forms based on modeled results and field data collected along reservoir reaches.

| Life Form | Field Observation | Modeled |
|---------------------------------|-------------------|---------------|
| Hydrophytes | -8.0 to +1.0 | -4.5 to +1.5 |
| Ruderal Annuals | -10.0 to +4.5 | -10.5 to +4.0 |
| Obligate Riparian Annuals | -5.5 to +4.0 | -5.0 to +3.5 |
| Obligate Riparian Perennials | -5.0 to +5.0 | -4.0 to +4.5 |
| Facultative Riparian Annuals | -3.0 to +4.0 | -2.5 to +3.5 |
| Facultative Riparian Perennials | -3.0 to +5.5 | -3.0 to +4.5 |

Table 3.4. Percentage of modeled vegetation points within the elevation range of life forms based on field data collected along reservoir reaches.

| Life form | Percentage |
|---------------------------------|------------|
| Hydrophytes | 99.5 |
| Ruderal Annuals | 99.3 |
| Obligate Riparian Annuals | 100 |
| Obligate Riparian Perennials | 100 |
| Facultative Riparian Annuals | 100 |
| Facultative Riparian Perennials | 100 |

Table 3.5. Differences in elevation (m) between modeled and actual measured life forms for each of the sub-reaches evaluated using HC_REM along reservoir reaches.

| Reach | Hydrophytes | Ruderal Annuals | Obligate Riparian Annuals | Obligate Riparian Perennials | Facultative Riparian Annuals | Facultative Riparian Perennials |
|---------------------------|--------------------|-----------------|---------------------------|------------------------------|------------------------------|---------------------------------|
| | LL-UL ¹ | LL-UL | LL-UL | LL-UL | LL-UL | LL-UL |
| Brownlee Headwaters | -1.0 - +1.5 | -1.0--1.0 | +1.5--+1.5 | -1.0--1.5 | +0.5--0.5 | -0.5--1.5 |
| Brownlee Main Reservoir | -1.5--+2.5 | -0.5--0.5 | - | -1.5-0.0 | -0.5-0.0 | - |
| | | | +2.5 | | | +1.0 |
| Brownlee Powder River Arm | +4.0-0.0 | -0.5--0.5 | - | -1.5-0.0 | -1.5--0.5 | -0.5--1.5 |
| | | | +3.5 | | | |
| Oxbow | 0--0.5 | -2.0--0.5 | N/A | -1.0--0.5 | - | -1.0--0.5 |
| | | | | | +0.5 | |
| Bypass | N/A ² | -1.0--1.5 | -2.0--0.5 | +0.5--+1.5 | -3.0--0.5 | +0.5--1.0 |
| Hells Canyon | -1.0-0.0 | -1.0--0.5 | N/A | -0.5--+1.0 | -0.5-0.0 | -0.5--1.5 |
| Average | +0.1--0.9 | -1.2--1.0 | -0.125- | -0.083- | -0.83- | -0.33- |
| | | | +1.75 | +0.083 | -0.167 | -0.83 |

¹ LL - lower limit of the elevation band; and UL - upper limit of the elevation band. For example, if LL is -1.0, the model results are 1.0 m lower than the actual observed vegetation.

² N/A - life form was not observed in the field.

Table 3.6. Percentage of modeled vegetation points within the observed elevation range of life forms based on field data collected in each of the reservoir reaches.

| Reach | Hydrophytes | Ruderal Annuals | Obligate Riparian Annuals | Obligate Riparian Perennials | Facultative Riparian Annuals | Facultative Riparian Perennials | Average |
|---------------------------|-------------|-----------------|---------------------------|------------------------------|------------------------------|---------------------------------|---------|
| Brownlee Headwaters | 65 | 98 | 94 | 94 | 100 | 81 | 88.7 |
| Brownlee Main Reservoir | 8 | 99 | 84 | 85 | 95 | 99 | 78.3 |
| Brownlee Powder River Arm | 100 | 99 | 29 | 94 | 36 | 95 | 75.5 |
| Oxbow | 96 | 60 | N/A | 80 | 95 | 83 | 82.8 |
| Bypass | N/A | 83 | 57 | 70 | 40 | 100 | 70.0 |
| Hells Canyon | 17 | 86 | N/A | 86 | 97 | 94 | 76.0 |
| Average | 57.2 | 87.5 | 66.0 | 84.8 | 77.2 | 92.0 | 78.6 |

Table 3.7. Comparison of Average Water Levels for the Hells Canyon Reservoirs under different operational scenarios (historic-, proposed-, and ROR operations).

| Reservoir Reach | Historic | Proposed | ROR |
|-----------------|----------|----------|--------|
| Brownlee | 2060.4 | 2060.4 | 2077.0 |
| Oxbow | 1802.1 | 1803.4 | 1805.0 |
| Hells Canyon | 1685.4 | 1687.2 | 1688.0 |

Table 3.8. Prominent species in each vegetation group.

| Vegetation Group | Species | Scientific Name | Common Name |
|---|---------------------|---------------------------------------|-------------------------------|
| (FRA) Facultative Riparian Annuals | HEAN | <i>Helianthus annuus</i> | common sunflower |
| | MEOF | <i>Melilotus officinalis</i> | yellow sweetclover |
| | MOVE | <i>Mollugo verticillata</i> | carpetweed |
| | POAV | <i>Polygonum aviculare</i> | prostrate knotweed |
| (FRP) Facultative Riparian Perennials | ACSA | <i>Acer saccharinum</i> | silver maple |
| | ALRH | <i>Alnus rhombifolia</i> | white alder |
| | CERE | <i>Celtis reticulata</i> | netleaf hackberry |
| | COST | <i>Cornus stolonifera</i> | red-osier dogwood |
| | ELAN | <i>Elaeagnus angustifolia</i> | Russian-olive |
| | FRPE | <i>Fraxinus pennsylvanica</i> | ash |
| | RUDI | <i>Rubus discolor</i> | Himalayan blackberry |
| | TORA | <i>Toxicodendron radicans</i> | poison-ivy |
| | ULAM | <i>Ulmus americana</i> | American elm |
| | ULPA | <i>Ulmus parvifolia</i> | Chinese elm |
| ULPU | <i>Ulmus pumila</i> | Siberian elm | |
| (HYD) Hydrophytes | IRPS | <i>Iris pseudoacorus</i> | yellow iris / yellow-flag |
| | POAM | <i>Polygonum amphibium</i> | Water smartweed |
| | SCAC | <i>Scirpus acutus</i> | common bulrush |
| (ORA) Obligate Riparian Annuals | EUGL | <i>Euphorbia glyptosperma</i> | corrgate-seeded spurge |
| | HEAL | <i>Heleochloa alopecuroides</i> | heleochloa |
| | POMO | <i>Polypogon monspeliensis</i> | rabbit foot polypogon |
| | POPE | <i>Polygonum persicaria</i> | spotted ladysthumb |
| | PORI | <i>Potentilla rivalis</i> | river potentilla / cinquefoil |
| (ORP) Obligate Riparian Perennials | AMFR | <i>Amorpha fruticosa</i> | false indigo |
| | PODE | <i>Populus deltoides</i> | plains cottonwood |
| | SAAL | <i>Salix alba</i> | European white willow |
| | SAEX | <i>Salix exigua</i> | coyote/sandbar willow |
| | SALA | <i>Salix lasiandra</i> | Pacific willow |
| | TASP | <i>Tamarix ramosissima/parviflora</i> | salt cedar complex |
| (RA) Ruderal Annuals | AMAL | <i>Amaranthus albus</i> | tumble pigweed |
| | AMAR | <i>Ambrosia artemisiifolia</i> | common ragweed |
| | AMRE | <i>Amaranthus retroflexus</i> | redroot pigweed |
| | LEPE | <i>Lepidium perfoliatum</i> | clasping pepperweed |
| | POLA | <i>Polygonum lapathifolium</i> | pale smartweed |
| | POOL | <i>Portulaca oleracea</i> | purselane |
| | TRTE | <i>Tribulus terrestris</i> | puncture vine |
| | XAST | <i>Xanthium strumarium</i> | common cocklebur |

Table 3.9. Comparison of elevation range (m, with respect to average water level) of life forms based on modeled results and field data collected in the flow-regulated reach below Hells Canyon Dam.

| Life form | Field | Model |
|---------------------------------|----------------|----------------|
| Hydrophytes | -0.5 to + 6.5 | -0.5 to + 6.5 |
| Ruderal Annuals | 0.0 to + 11.5 | 0.0 to + 11.5 |
| Obligate Riparian Annuals | -1.0 to + 9.0 | -1.0 to + 8.5 |
| Obligate Riparian Perennials | +0.5 to + 8.0 | +0.5 to + 9.5 |
| Facultative Riparian Annuals | +0.5 to + 11.0 | +0.5 to + 11.0 |
| Facultative Riparian Perennials | -1.0 to + 11.0 | -1.0 to + 11.0 |

Table 3.10. Percentage of modeled vegetation points situated within elevation range of life forms based on field data collected in the flow-regulated reach below Hells Canyon Dam.

| Life form | Percentage |
|---------------------------------|------------|
| Hydrophytes | 100 |
| Ruderal Annuals | 100 |
| Obligate Riparian Annuals | 100 |
| Obligate Riparian Perennials | 99.7 |
| Facultative Riparian Annuals | 100 |
| Facultative Riparian Perennials | 100 |

Table 3.11. Percentage of modeled vegetation points situated within the elevational range of life forms based on field data collected in the flow-regulated reach below Hells Canyon Dam.

| Substrate | Hydrophyte | Ruderal Annual | Obligate Riparian Annual | Obligate Riparian Perennial | Facultative Riparian Annual | Facultative Riparian Perennial |
|------------------------|--------------------|----------------|--------------------------|-----------------------------|-----------------------------|--------------------------------|
| | LL-UL ¹ | LL-UL | LL-UL | LL-UL | LL-UL | LL-UL |
| Sand/ Fines | N/A ² | -1.0-+1.0 | -2.0-+1.5 | +0.5-+0.5 | 0.0-+3.0 | -2.0-+2.5 |
| Coarse (with fines) | +1.0-0.0 | 0.0-0.0 | -0.5--0.5 | +0.5-+3.0 | 0.0-0.0 | -0.5-0.0 |
| Coarse (w/o fines) | -0.5-+2.5 | 0.0-+0.5 | - +2.5 | -1.0-+2.0 | 0.0-0.0 | 0.0--2.5 |
| Rock | N/A | -3.0-+3.0 | N/A | -6.5--2.5 | -3.0-+4.0 | -2.0-0.0 |
| Average | +0.1-+0.6 | -1.2-+1.1 | -0.8-+0.8 | -1.6-+0.8 | -0.8-+1.8 | -1.1-0.0 |

¹ LL – lower limit of the elevation band; and UL –upper limit of the elevation band. The numbers under each category are the absolute differences in elevation (m) between the modeled results to the field data.

² N/A means that life form was not observed in the field.

Table 3.12. Percentage of modeled vegetation points situated within the elevation range of field data by life form and substrate in the flow-regulated reach below Hells Canyon Dam.

| Substrate | Hydro-phyte | Ruderal Annual | Obligate Riparian Annual | Obligate Riparian Perennial | Facultative Riparian Annual | Facultative Riparian Perennial | Average |
|-----------------------|-------------|----------------|--------------------------|-----------------------------|-----------------------------|--------------------------------|---------|
| Sand/ Fines | N/A | 98 | 80 | 99 | 95 | 86 | 91.6 |
| Coarse (w-fines) | 100 | 100 | 95 | 99 | 100 | 100 | 99.0 |
| Coarse (w/o-fines) | 25 | 99 | 88 | 56 | 100 | 100 | 78.0 |
| Rock | N/A | 14 | N/A | 0 | 0 | 71 | 42.5 |
| Average | 62.5 | 77.8 | 87.7 | 63.5 | 73.8 | 89.3 | 77.8 |

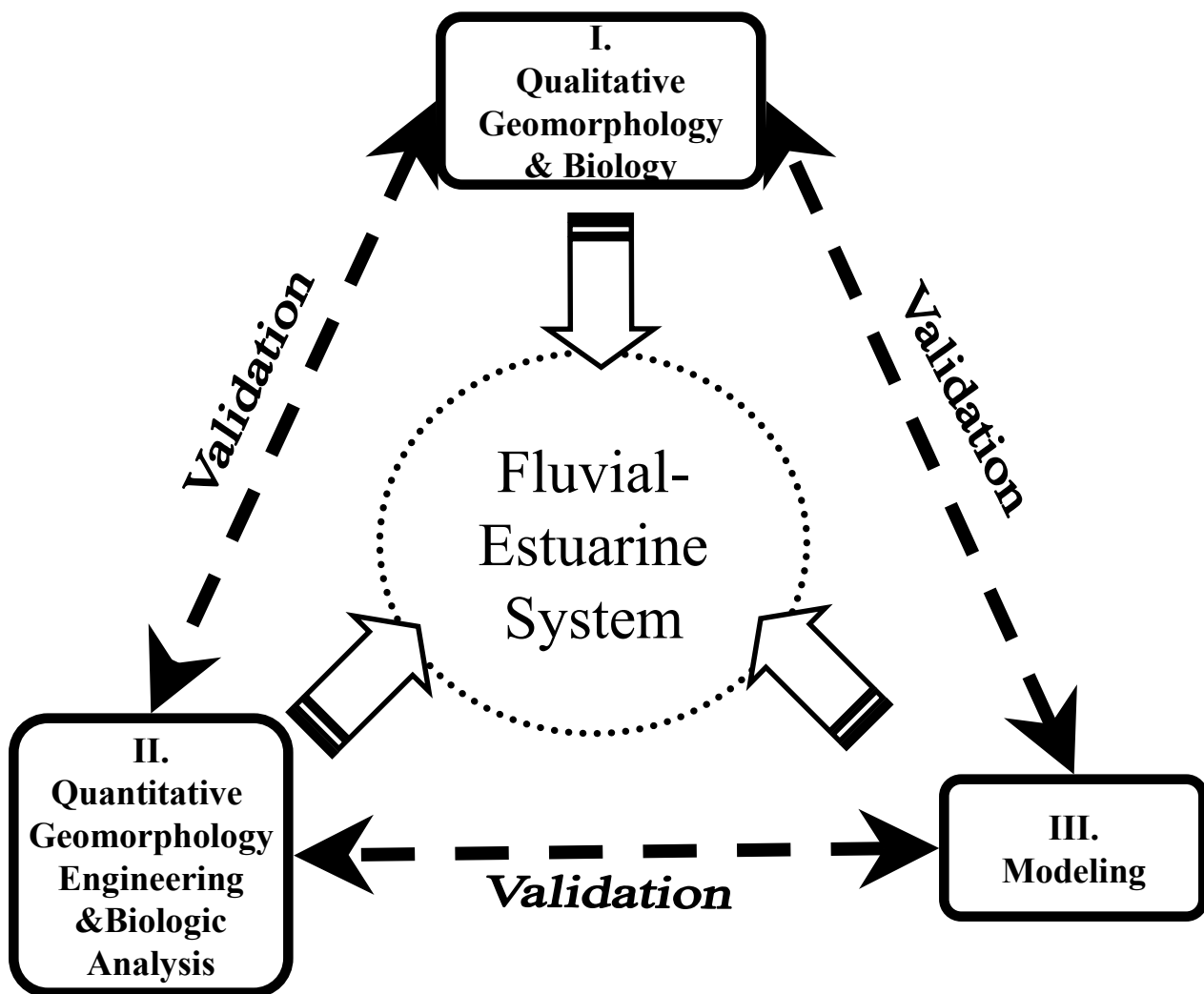
Table 3.13. Differences in elevation (m) between modeled and measured life forms for each substrate evaluated using HC_REM in the flow-regulated reach below Hells Canyon Dam.

| Substrate | Life Form | | | | | |
|------------------------|--------------------|----------------|--------------------------|-----------------------------|------------------------------|---------------------------------|
| | Hydrophyte | Ruderal Annual | Obligate Riparian Annual | Obligate Riparian Perennial | Facul-tative Riparian Annual | Facul-tative Riparian Perennial |
| | LL-UL ¹ | LL-UL | LL-UL | LL-UL | LL-UL | LL-UL |
| Sand/ Fines | +1.0-+1.0 | +0.5- 0.0 | -0.5- -0.5 | 0.0- -0.5 | 0.0- -0.5 | -0.5- +0.5 |
| Coarse (with fines) | +0.5-1.0 | 0.0- +1.0 | 0.0- +0.5 | +1.0- 0.0 | 0.0- +1.5 | 0.0- 0.0 |
| Coarse (w/o fines) | 0.0-+2.0 | 0.0- +0.5 | +1.0- 0.0 | 0.0- -1.0 | -0.5- 0.0 | -0.5- 0.0 |
| Rock | -0.5- -0.5 | +0.5- -1.0 | 0.0-+0.5 | 0.0- +3.0 | 0.0- +1.5 | +0.5- 0.0 |
| Average | +0.2-+0.4 | +0.2- +0.1 | +0.1- +0.1 | +0.2- +0.4 | -0.1- +0.6 | -0.1- +0.1 |

¹ LL-lower limit of the elevation band; and UL-upper limit of the elevation band. The numbers under each category are the absolute differences in elevation (m) between the modeled results to the field data.

Table 3.14. Percentage of Modeled Vegetation Points situated within the Elevation Range of Field Data by Life Form and Substrate by Quadrat compared to field data in the flow-regulated reach below Hells Canyon Dam.

| Substrate | Hydro-phyte | Ruderal Annual | Obligate Riparian Annual | Obligate Riparian Perennial | Facultative Riparian Annual | Facultative Riparian Perennial | Average |
|-----------------------|-------------|----------------|--------------------------|-----------------------------|-----------------------------|--------------------------------|---------|
| Sand/ Fines | N/A | 100 | 99 | 100 | 100 | 99 | 99.6 |
| Coarse (w-fines) | 100 | 99 | 100 | 100 | 99 | 100 | 99.7 |
| Coarse (w/o-fines) | 60 | 99 | 100 | 100 | 93 | 100 | 92.0 |
| Rock | 0 | 100 | 75 | 40 | 97 | 100 | 68.7 |
| Average | 40.0 | 99.5 | 93.5 | 85.0 | 97.3 | 99.8 | 85.9 |



A conceptual schematic of the three-level approach for determining geomorphic, sediment transport and biologic response . Validation must occur between all three levels to assure that reasonable results have been achieved.

Figure 3.1. Conceptual Schematic

CHANWID CALIBRATION -- P. AT GOTHENBURG

N=.03 S=.0013 VF=.94SF=.25 QH=20K QL=8K

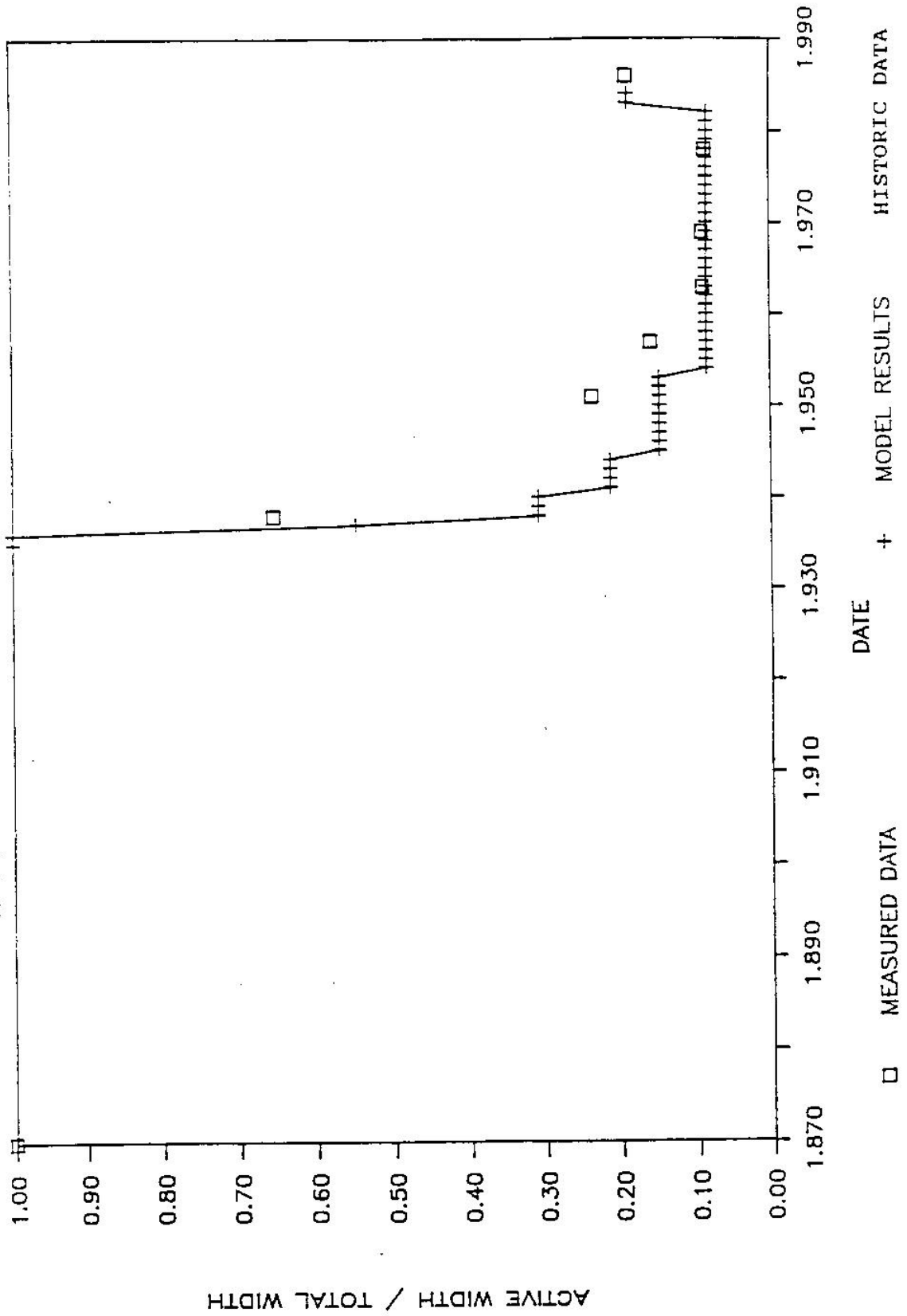


Figure 3.2.

Figure 3.3. Timing of seed dispersal for select plant species along the Hells Canyon Complex of reservoirs. The abbreviations for all species are defined in Appendix 1.

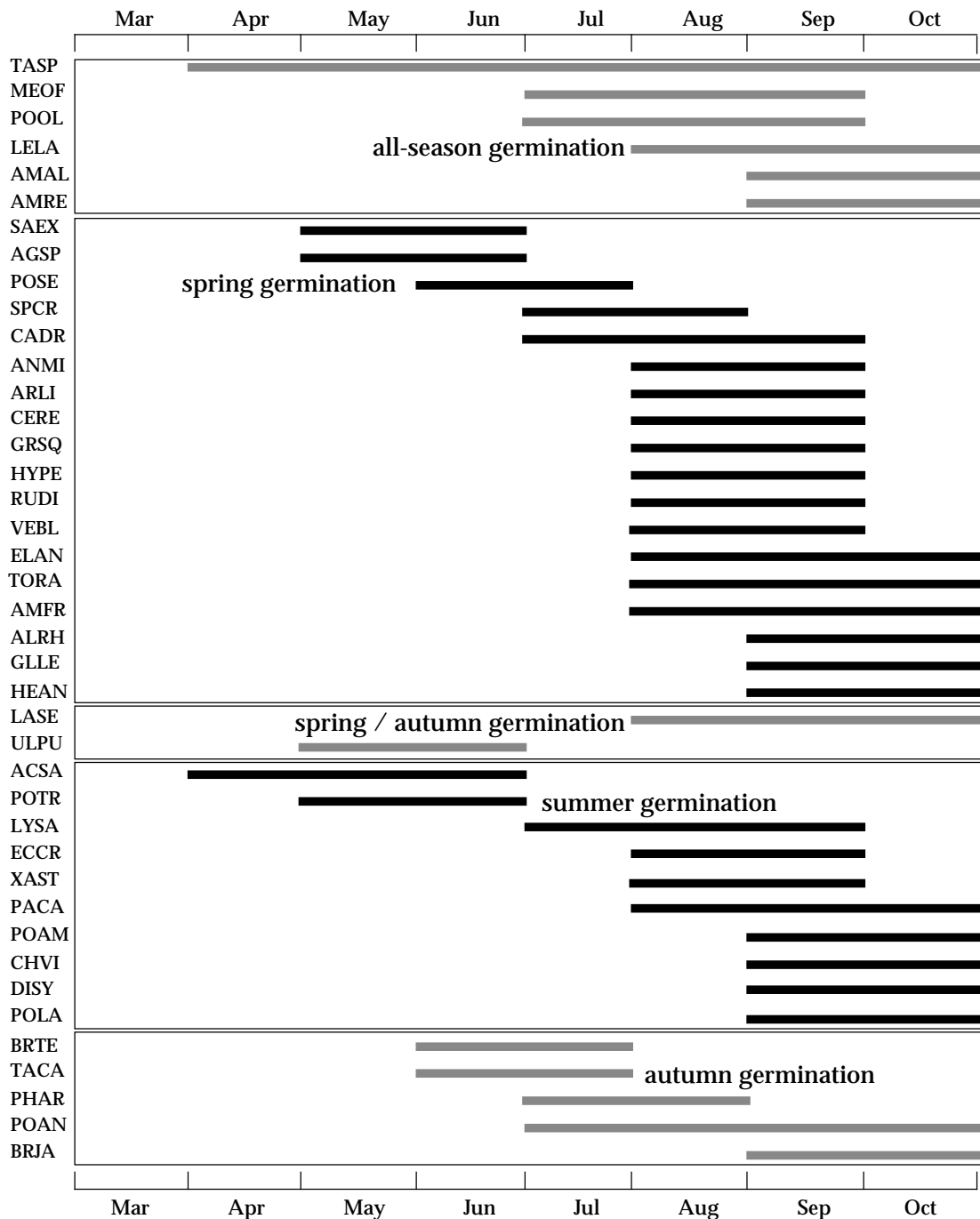


Figure 3.4. Timing of seed germination for select plant species along the Hells Canyon Complex of reservoirs. The abbreviations for all species are defined in Appendix 1.

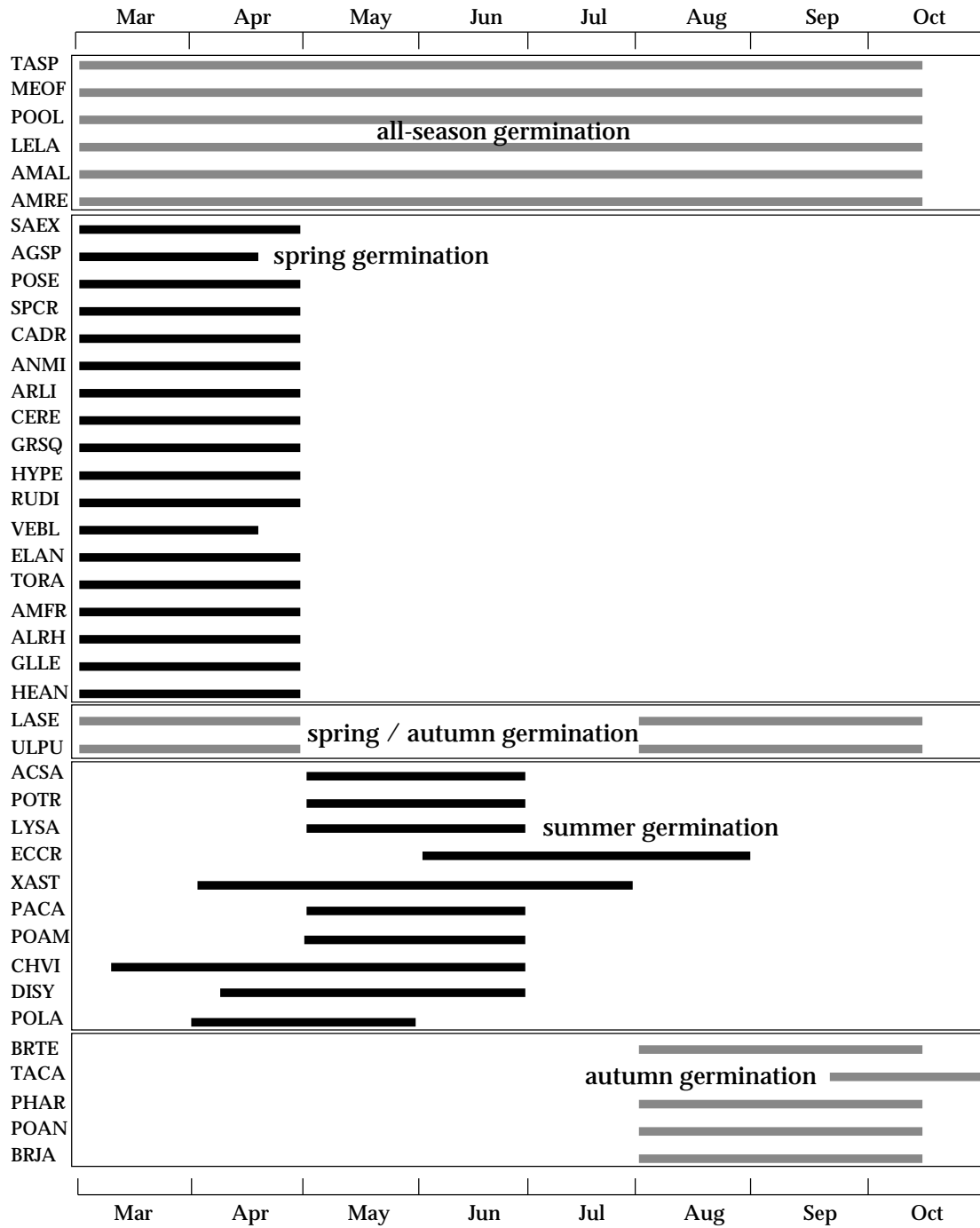


Figure 3.5. Proportion of quadrats at each 0.5m increment in elevation where each vegetation group is modelled to occur according to the Historic Operations scenario at year 40 versus the proportion of quadrats where vegetation presently exists.

Snake River (SN)

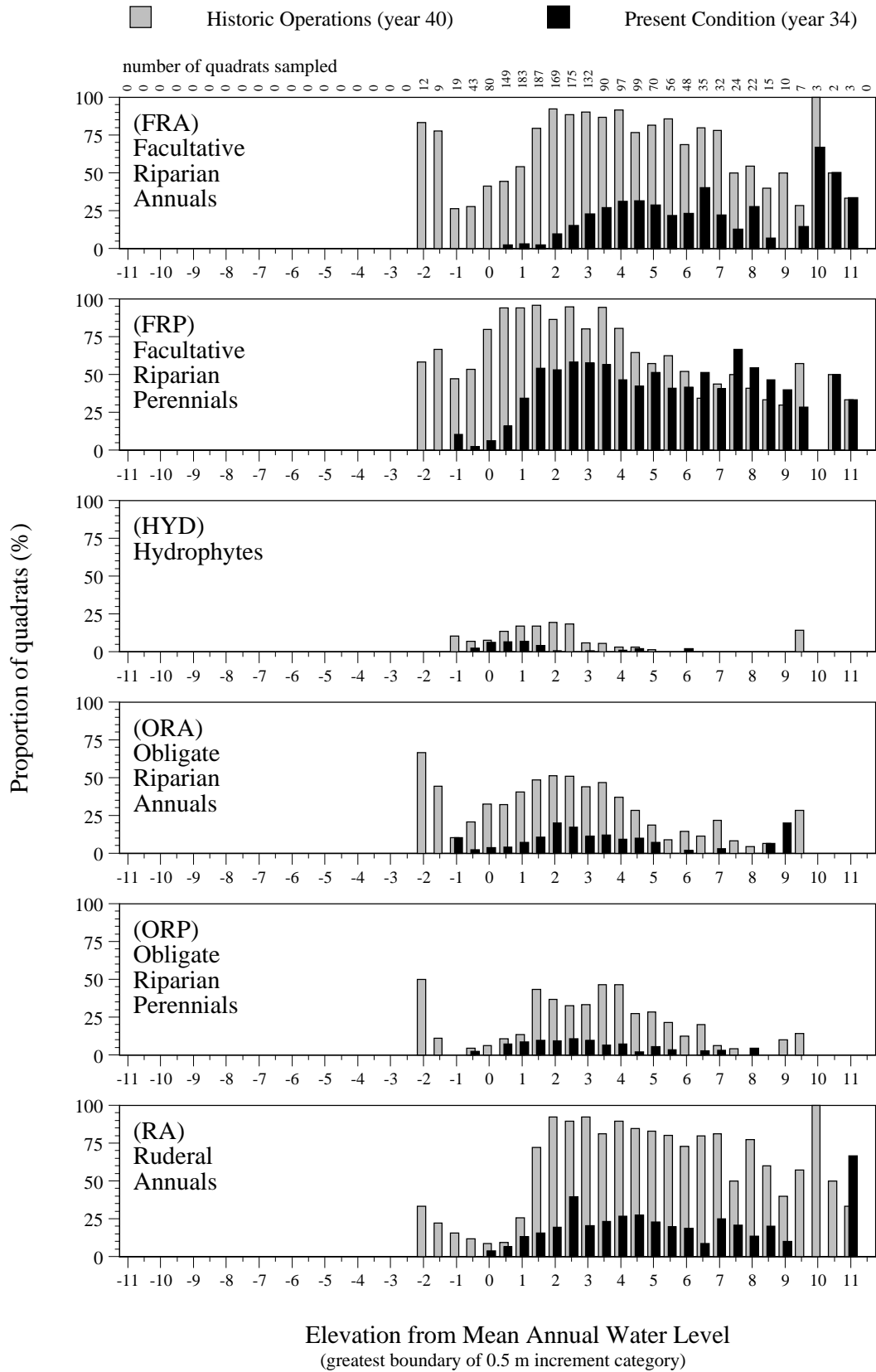


Figure 3.7. Proportion of quadrats at each 0.5m increment in elevation along the Brownlee Headwater (BH) where each vegetation group is modelled to occur according to the Proposed IPC and Run of River scenarios at year 100.

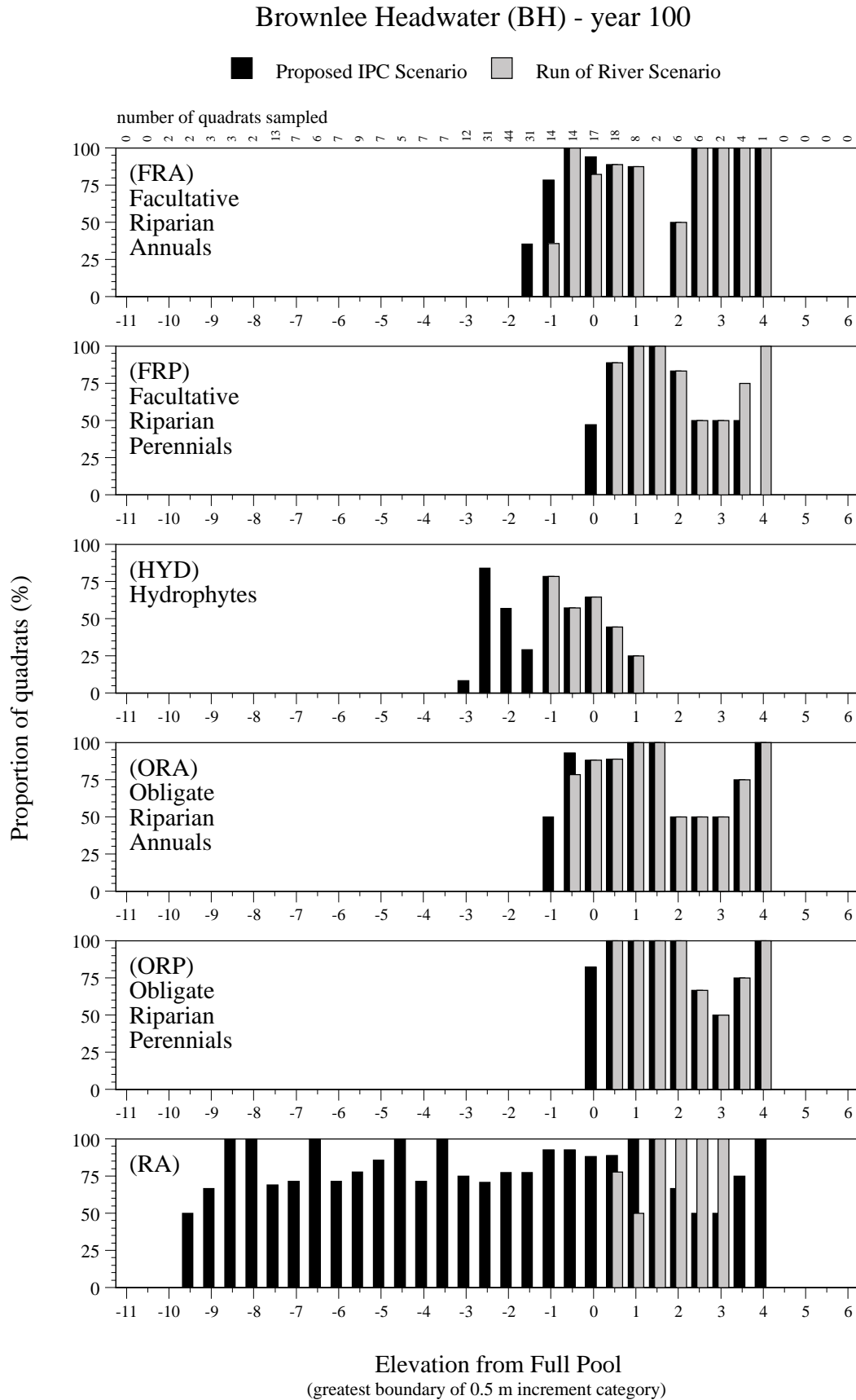


Figure 3.8. Sum of proportions of quadrats along the Brownlee Reservoir - Headwater (BH) that are occupied by each vegetation group according to the Proposed IPC and Run of River scenarios at year 100. The value above each bar indicates the percent difference relative to the Run of River Scenario

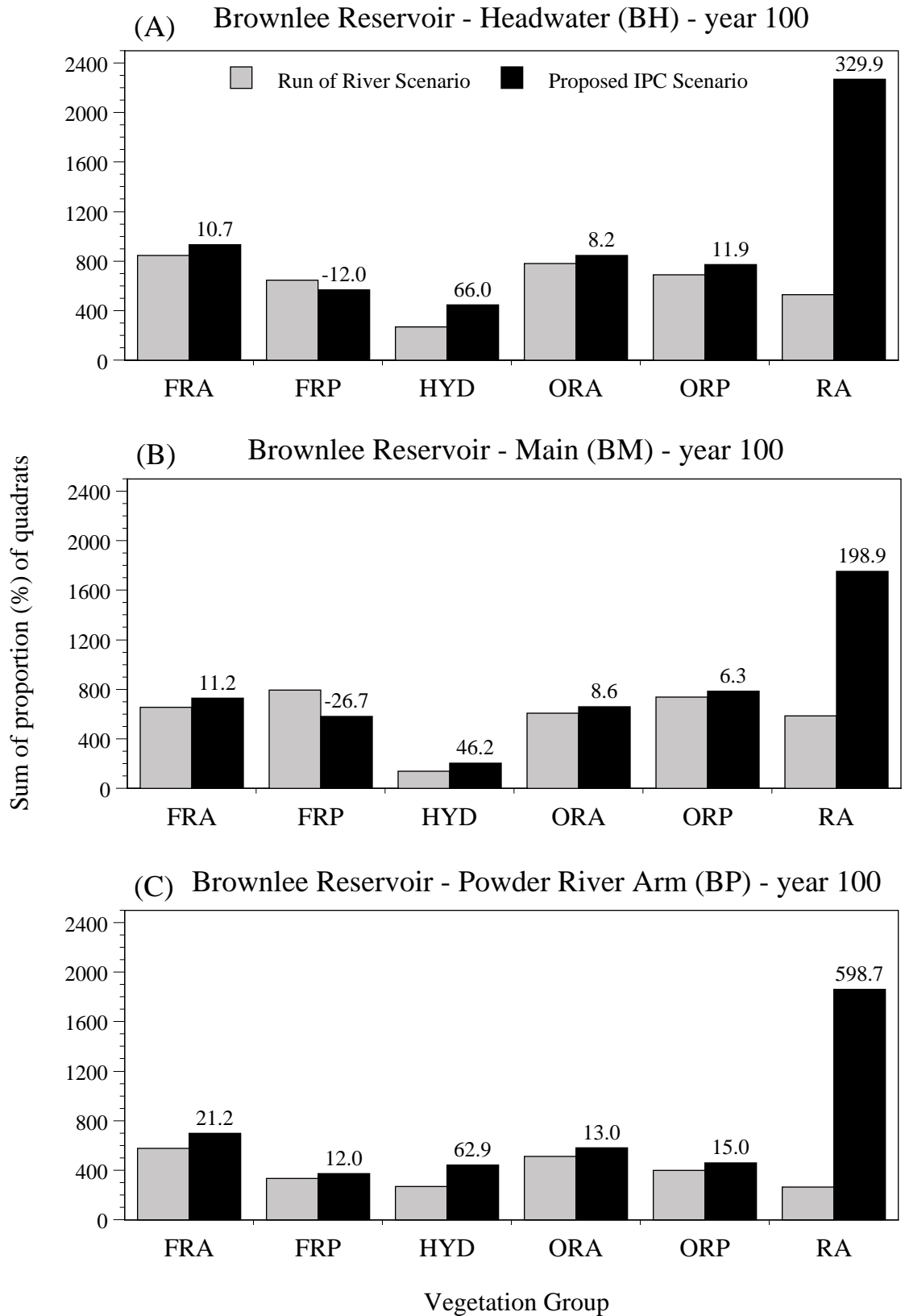


Figure 3.9. Average elevation versus average number of years since establishment for quadrats along the Brownlee Headwater (BH) that are occupied by each vegetation group at year 110 according to the Run of River and Proposed IPC scenarios (bars indicate +/- 1 SD).

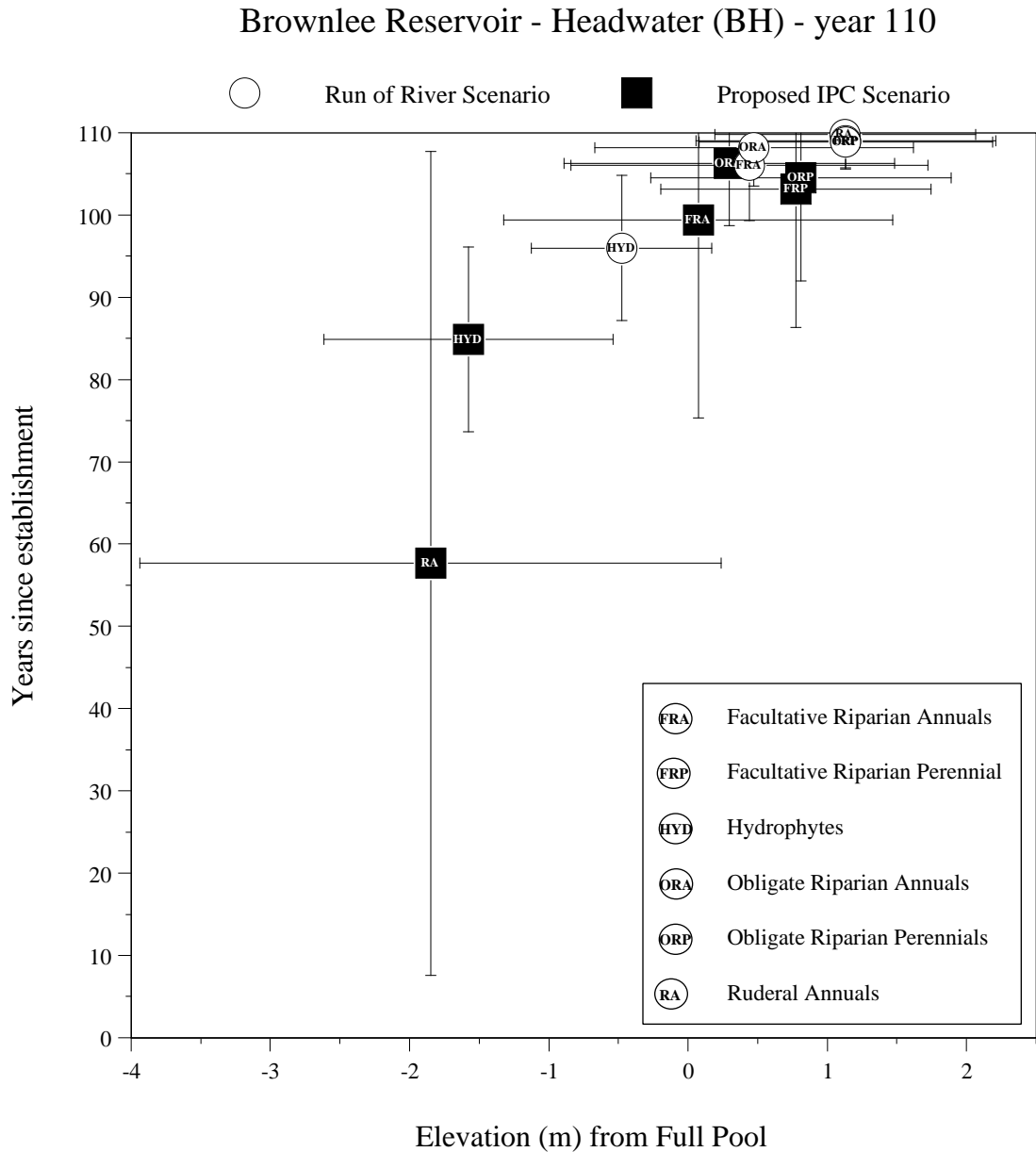


Figure 3.10. Proportion of quadrats at each 0.5m increment in elevation along the Brownlee Reservoir - Main (BM) where each vegetation group is modelled to occur according to the Proposed IPC and Run of River scenarios at year 100.

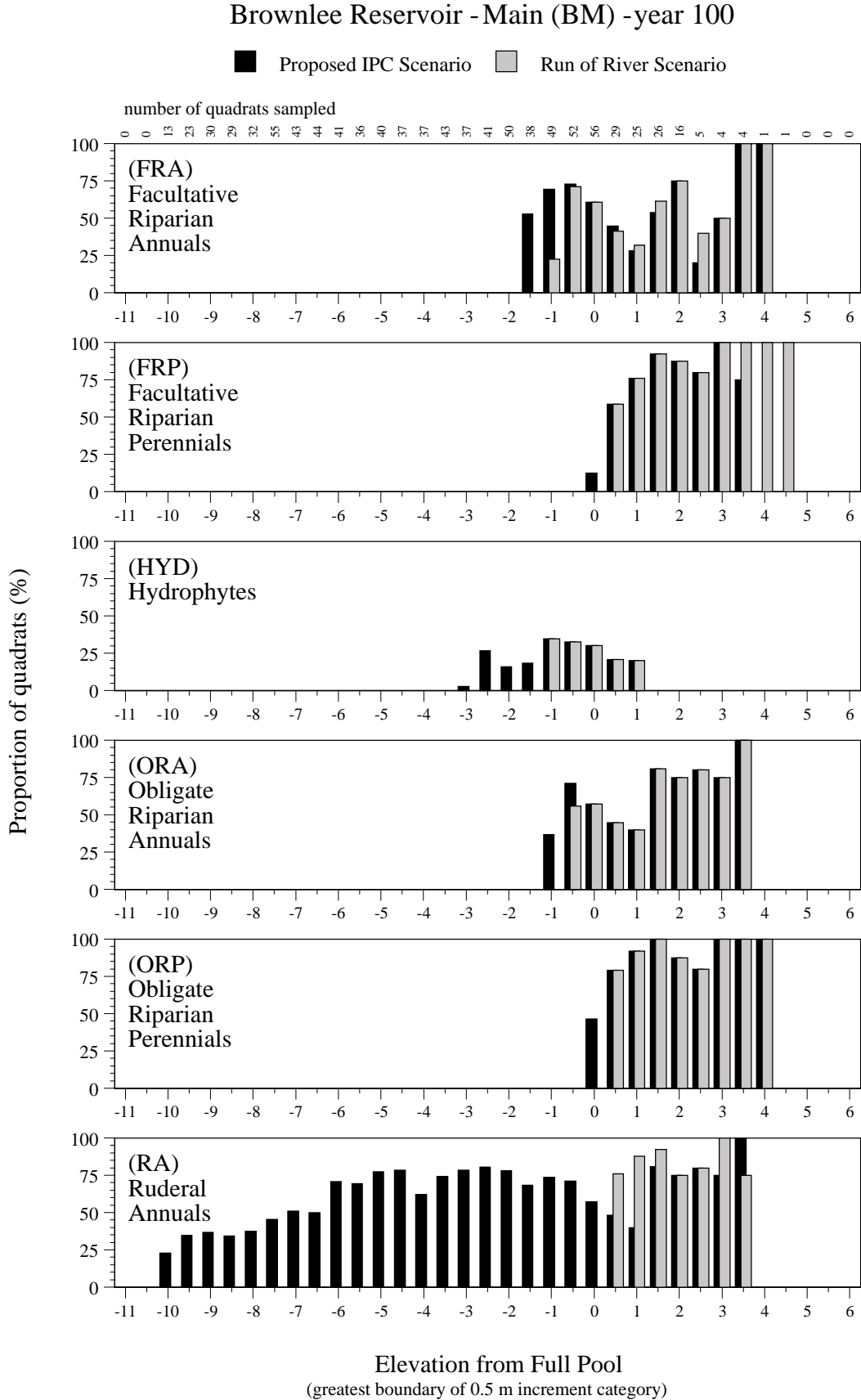


Figure 3.11. Average elevation versus average number of years since establishment for quadrats along Brownlee Reservoir - Main (BM) that are occupied by each vegetation group at year 110 according to the Run of River and Proposed IPC scenarios (bars indicate +/- 1 SD).

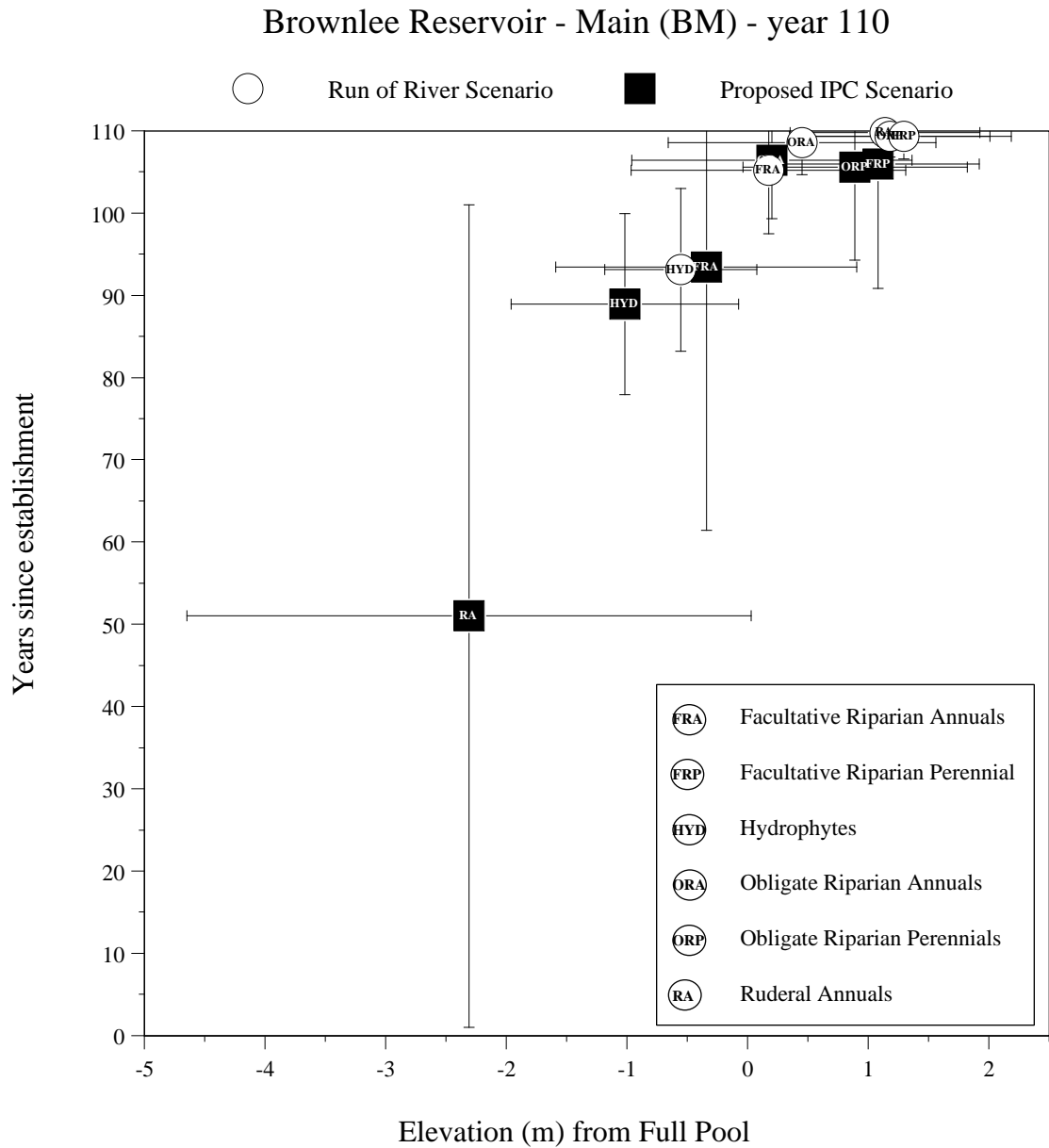


Figure 3.12. Proportion of quadrats at each 0.5m increment in elevation along the Brownlee Reservoir - Powder River Arm (BP) where each vegetation group is modelled to occur according to the Proposed IPC and Run of River scenarios at year 100.

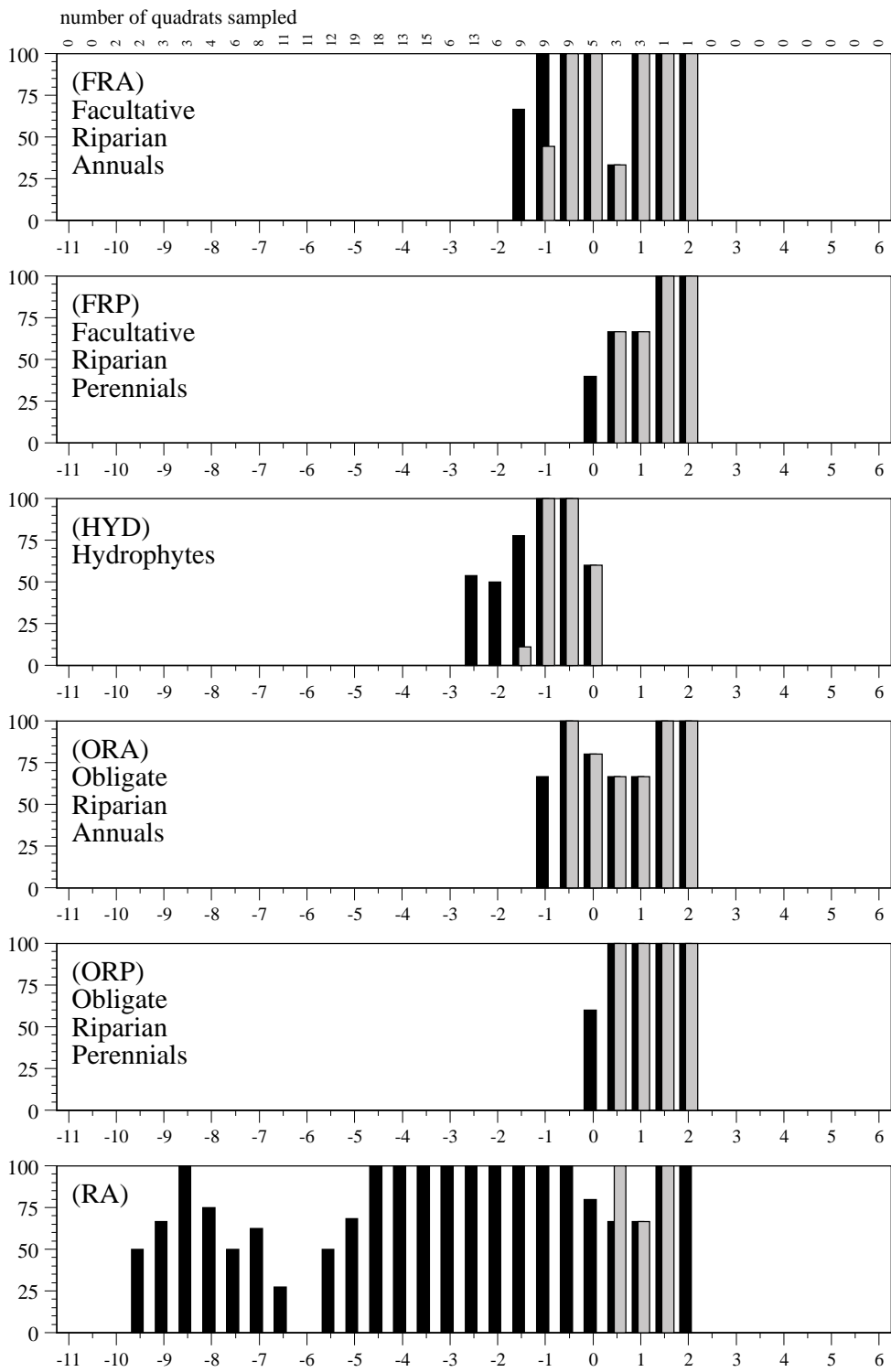
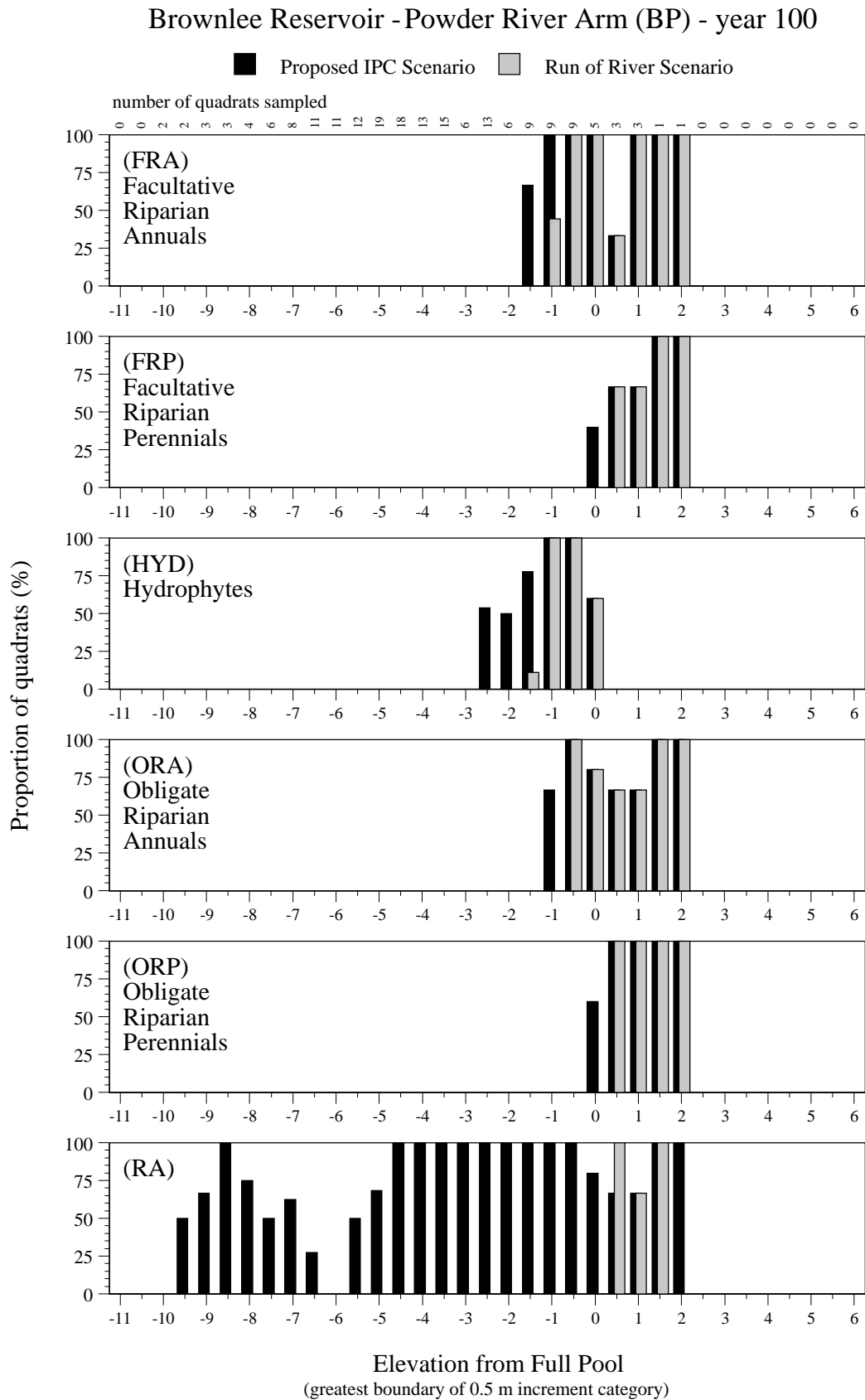


Figure 3.13. Average elevation versus average number of years since establishment for quadrats along the Brownlee Reservoir - Powder River Arm (BP) that are occupied by each vegetation group at year 110 according to the Run of River and Proposed IPC scenarios (bars indicate +/- 1 SD).

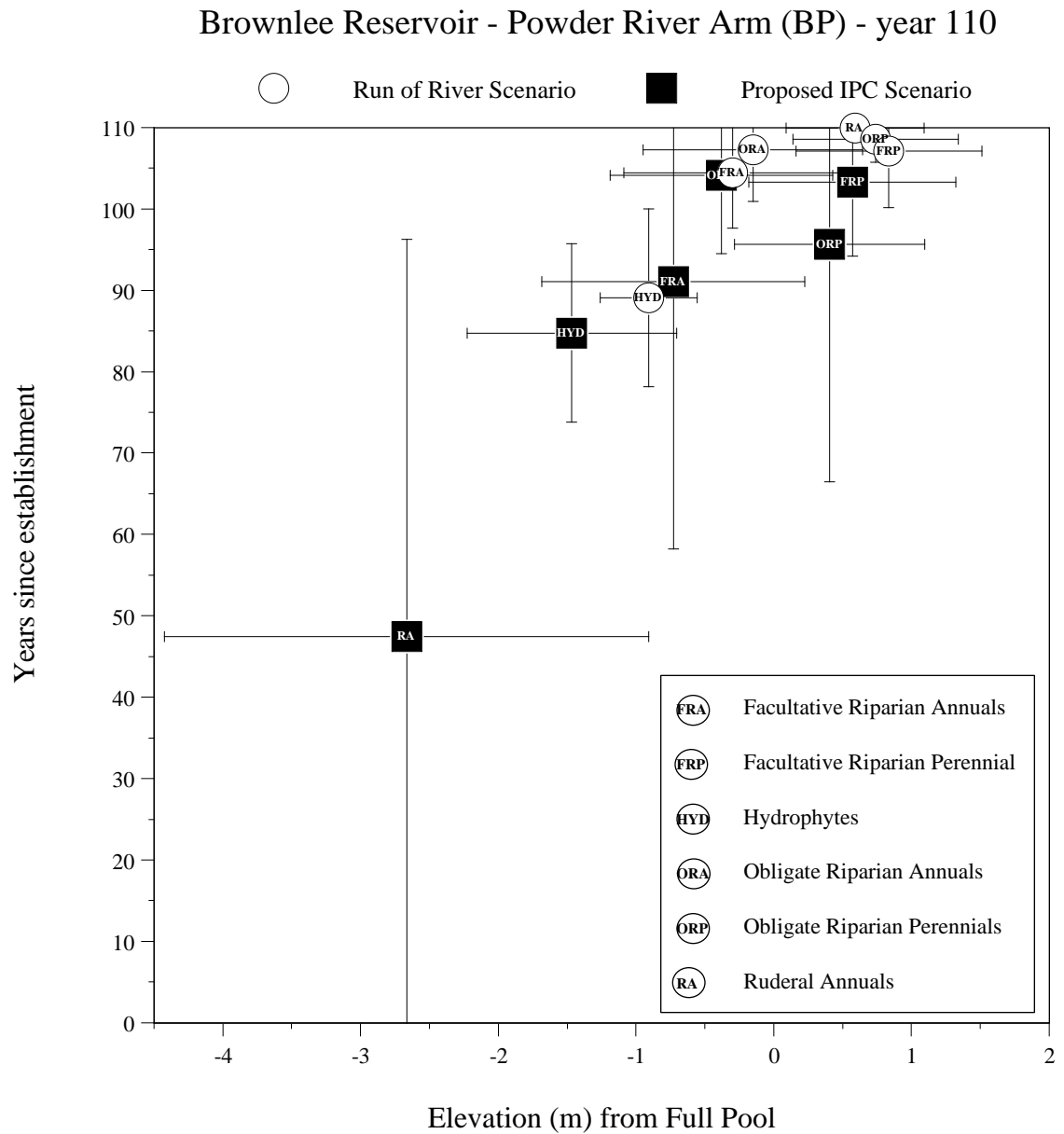


Figure 3.14. Proportion of quadrats at each 0.5m increment in elevation along the Oxbow Reservoir - Main (OM) where each vegetation group is modelled to occur according to the Proposed IPC and Run of River scenarios at year 100.

Oxbow Reservoir - Main (OM) - year 100

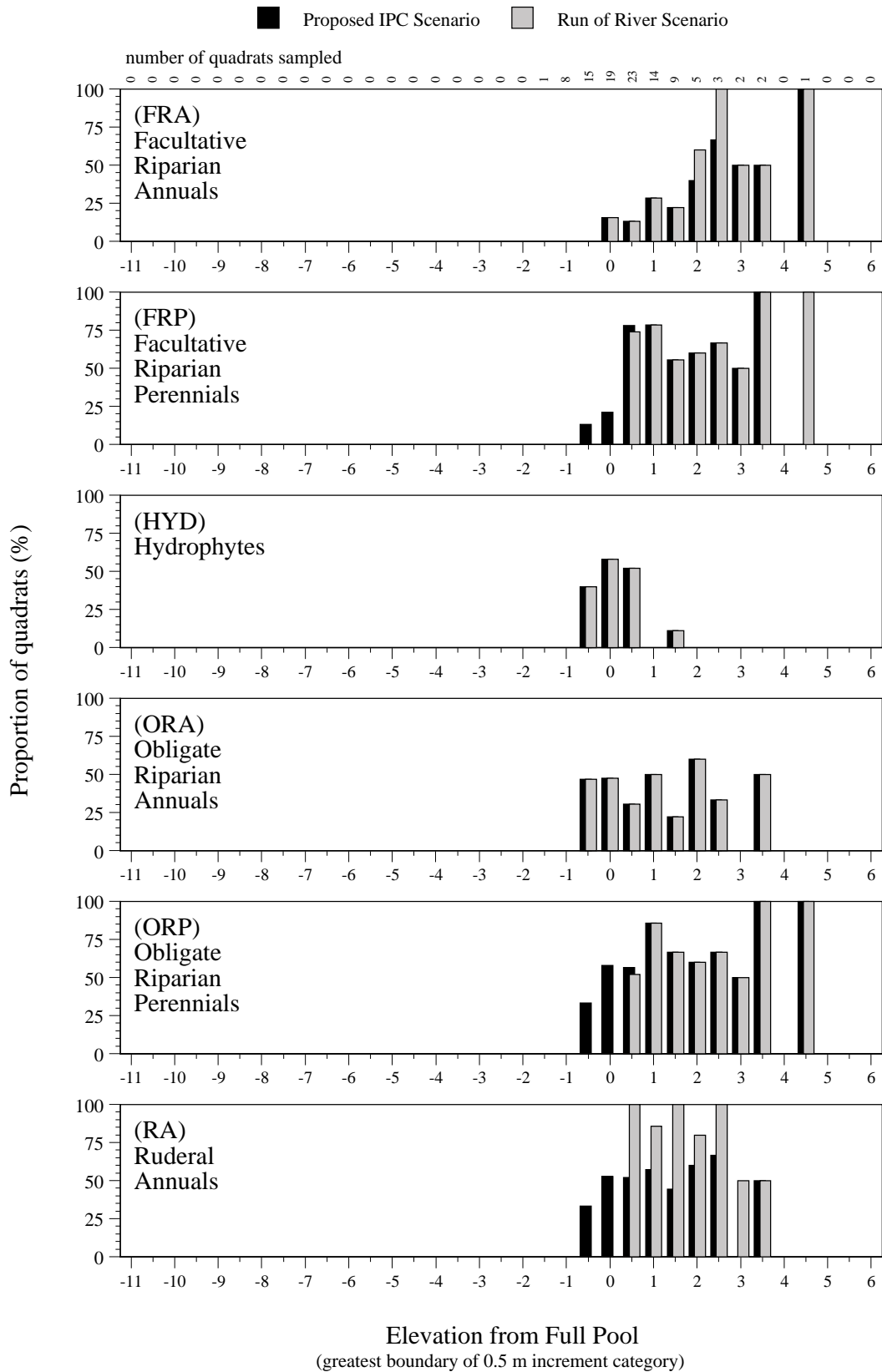


Figure 3.15. Sum of proportions of quadrats along the Oxbow Reservoir - Main (OM) that are occupied by each vegetation group according to the Proposed IPC and Run of River scenarios at year 100. The value above each bar indicates the percent difference relative to the Run of River Scenario.

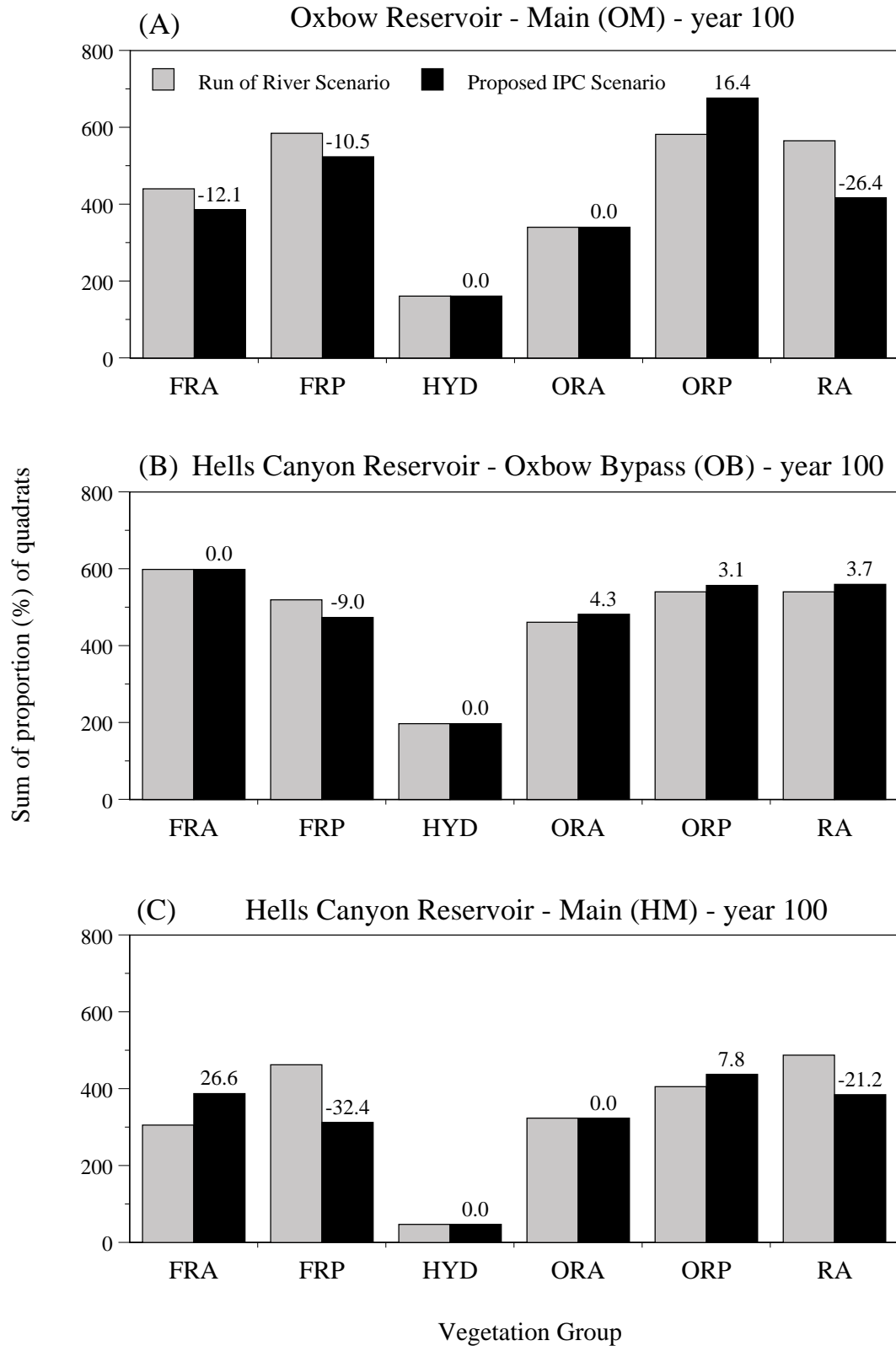


Figure 3.16. Average elevation versus average number of years since establishment for quadrats along the Oxbow Reservoir - Main (OM) that are occupied by each vegetation group at year 110 according to the Run of River and Proposed IPC scenarios (bars indicate +/- 1 SD).

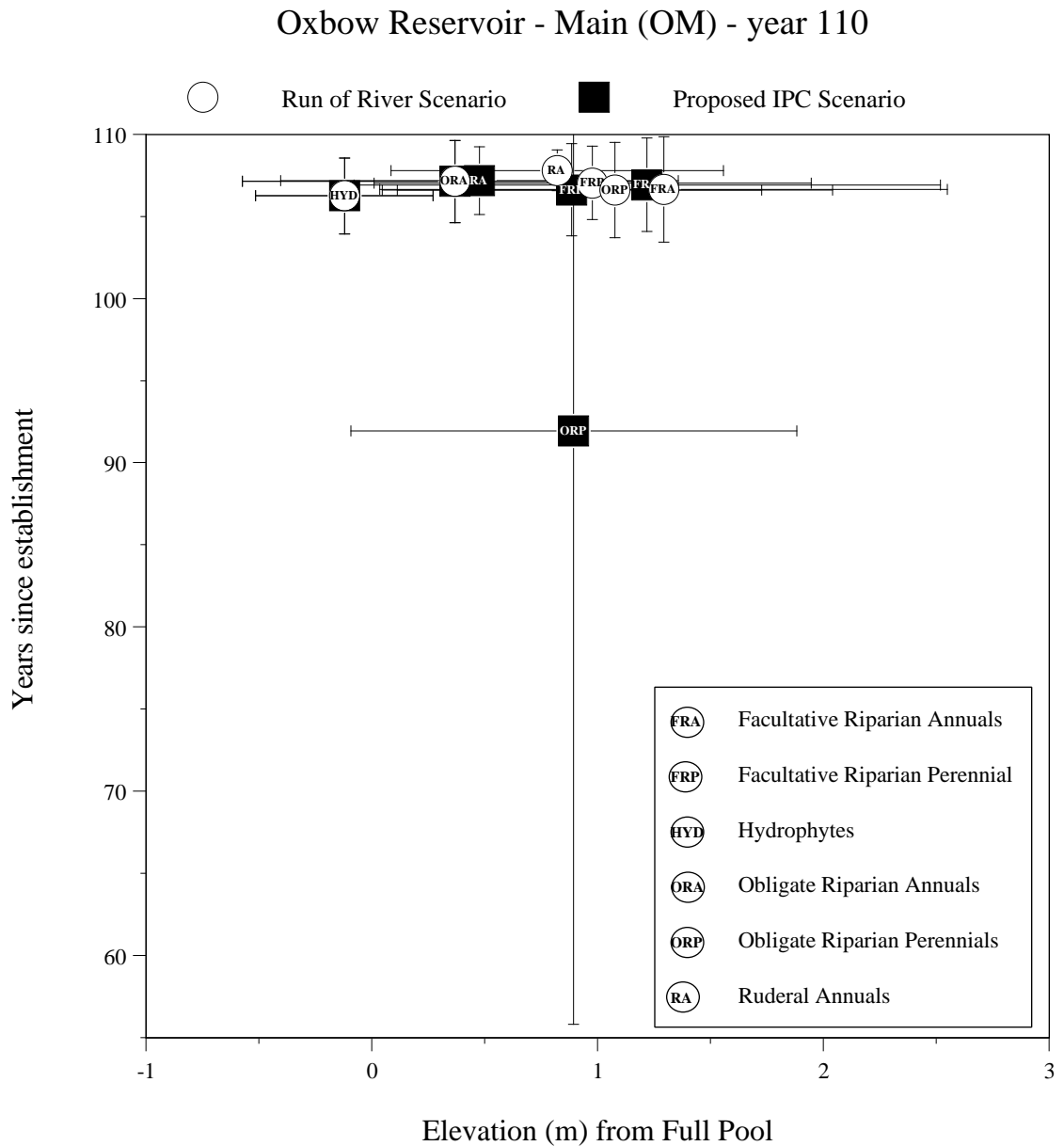


Figure 3.17. Proportion of quadrats at each 0.5m increment in elevation along the Hells Canyon Reservoir - Oxbow Bypass (OB) where each vegetation group is modelled to occur according to the Proposed IPC and Run of River scenarios at year 100.

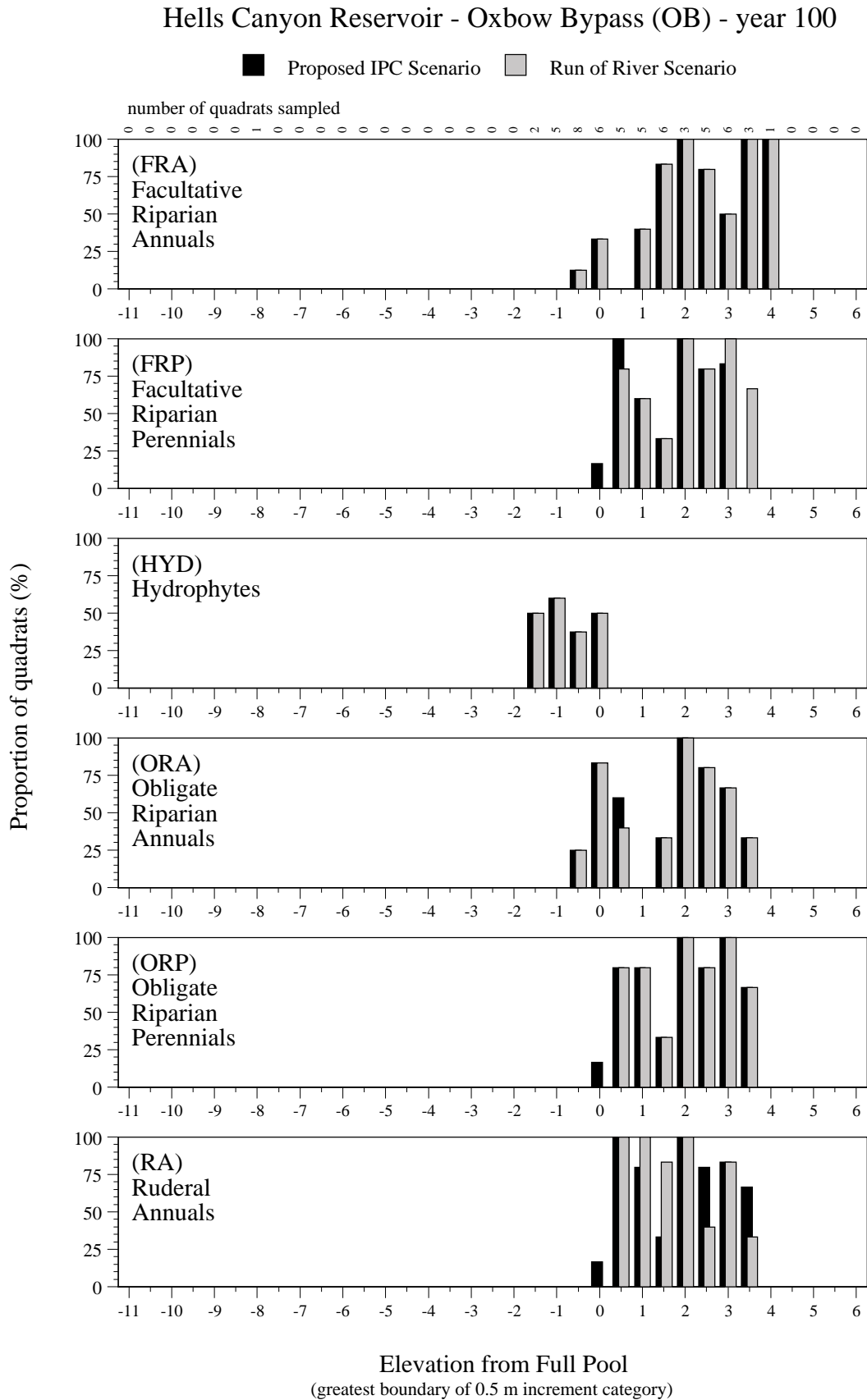


Figure 3.18. Average elevation versus average number of years since establishment for quadrats along the Hells Canyon Reservoir - Oxbow Bypass (OB) that are occupied by each vegetation group at year 110 according to the Run of River and Proposed IPC scenarios (bars indicate +/- 1 SD).

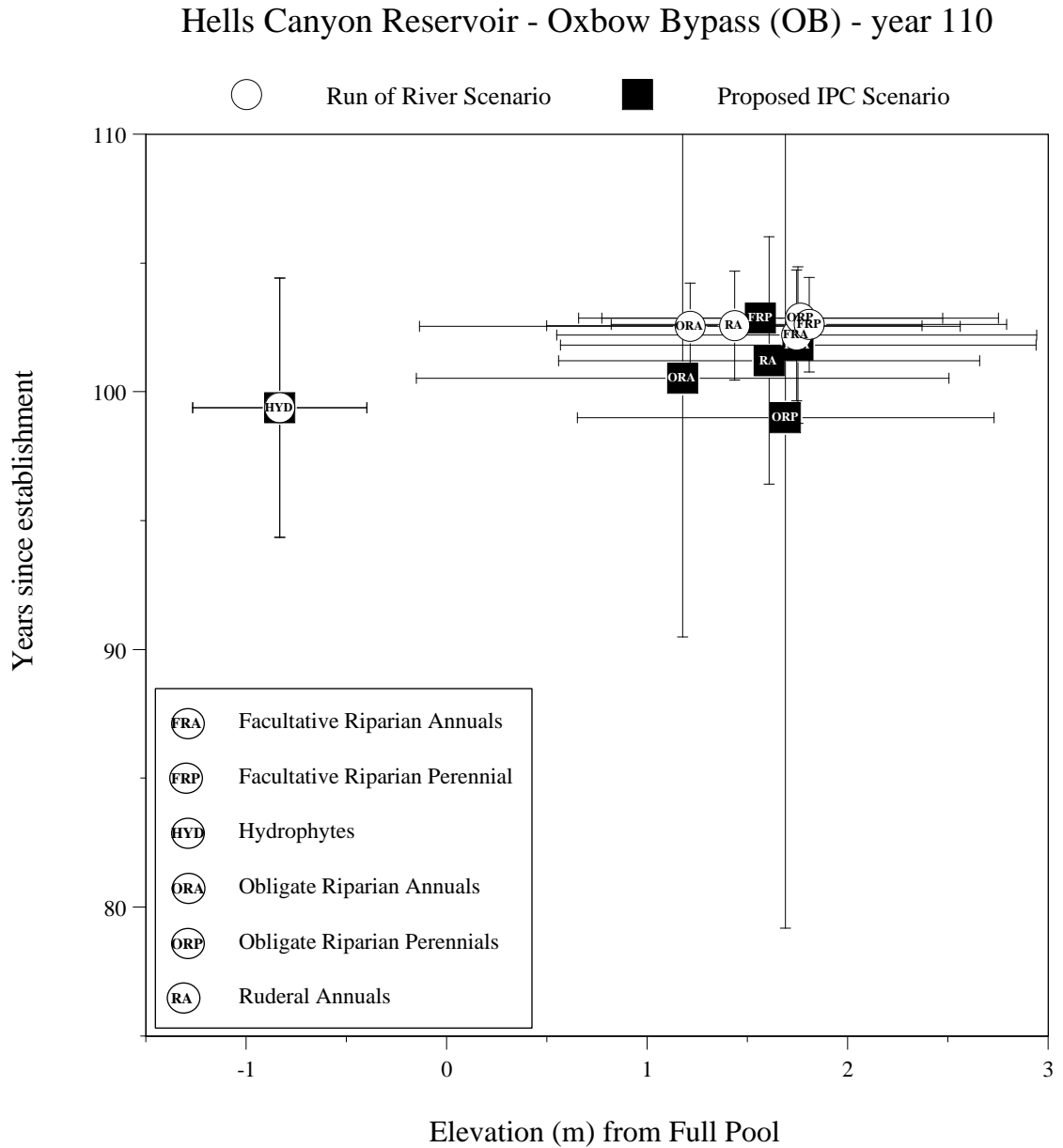


Figure 3.19. Proportion of quadrats at each 0.5m increment in elevation along the Hells Canyon Reservoir - Main (HM) where each vegetation group is modelled to occur according to the Proposed IPC and Run of River scenarios at year 100.

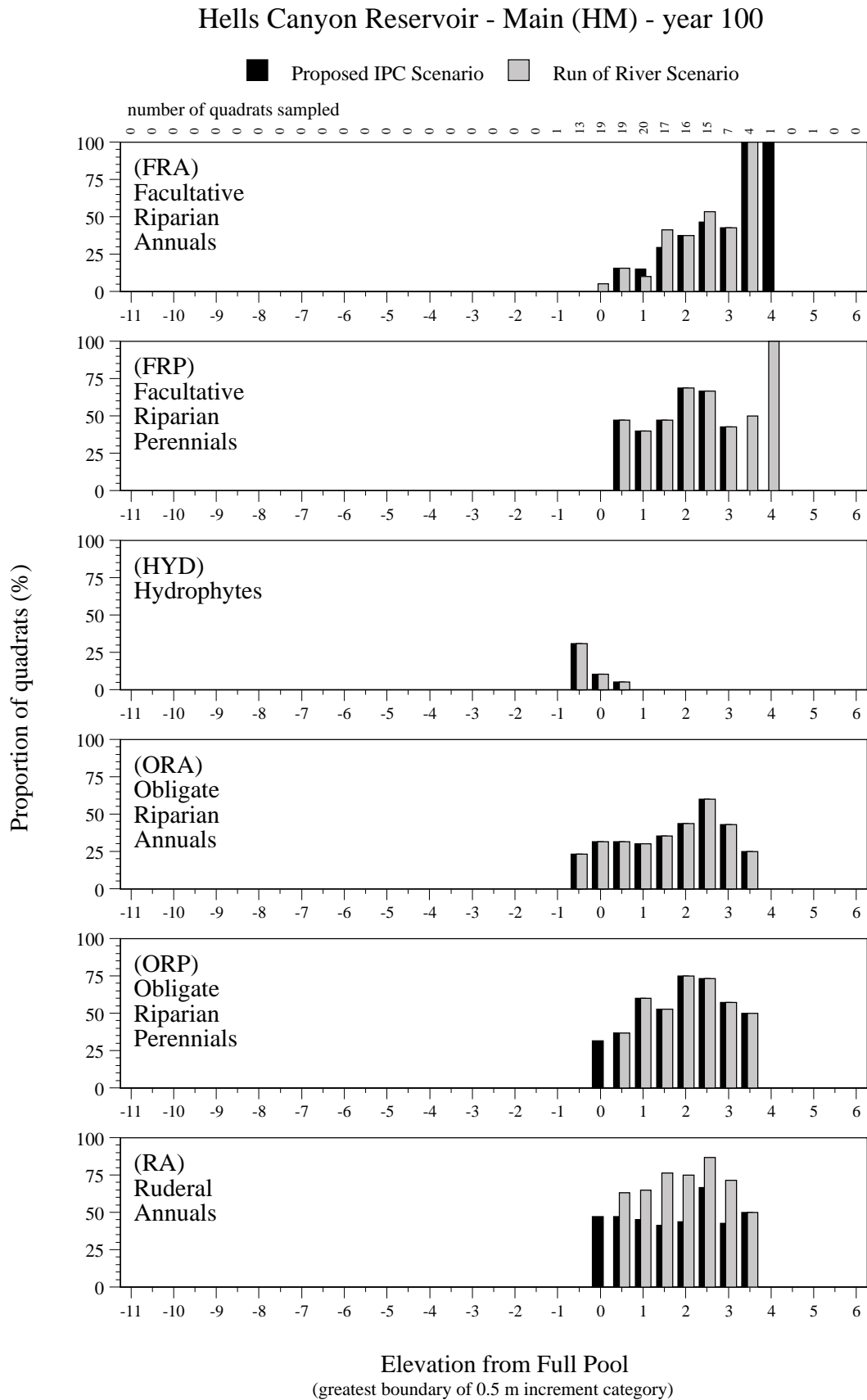


Figure 3.20. Average elevation versus average number of years since establishment for quadrats along the Hells Canyon Reservoir - Main (HM) that are occupied by each vegetation group at year 110 according to the Run of River and Proposed IPC scenarios (bars indicate +/- 1 SD).

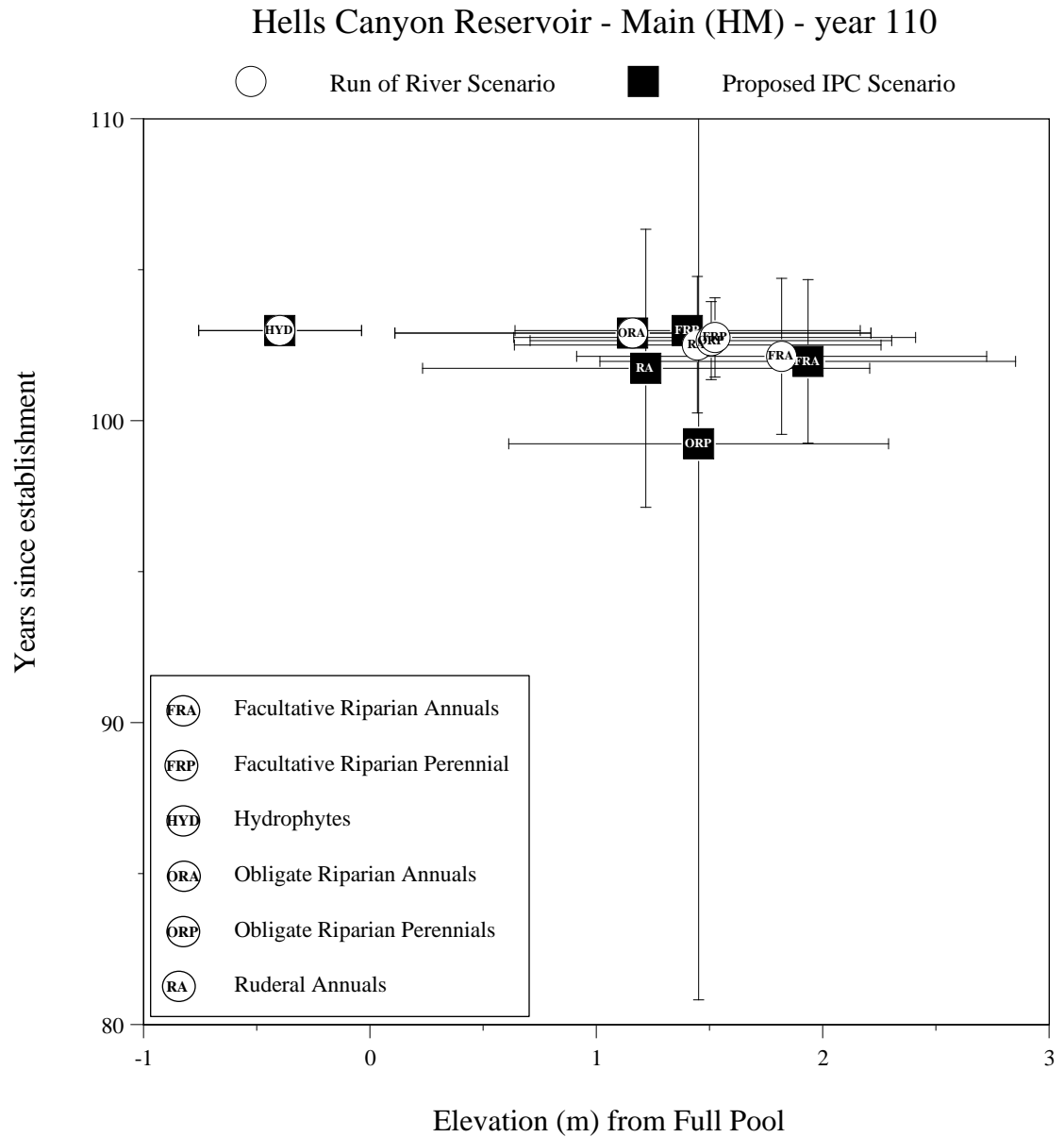


Figure 3.21. Proportion of quadrats at each 0.5m increment in elevation along the Snake River Reach (SN) where each vegetation group is modelled to occur according to the Proposed IPC and Run of River scenarios at year 100.

Snake River (SN) - year 100

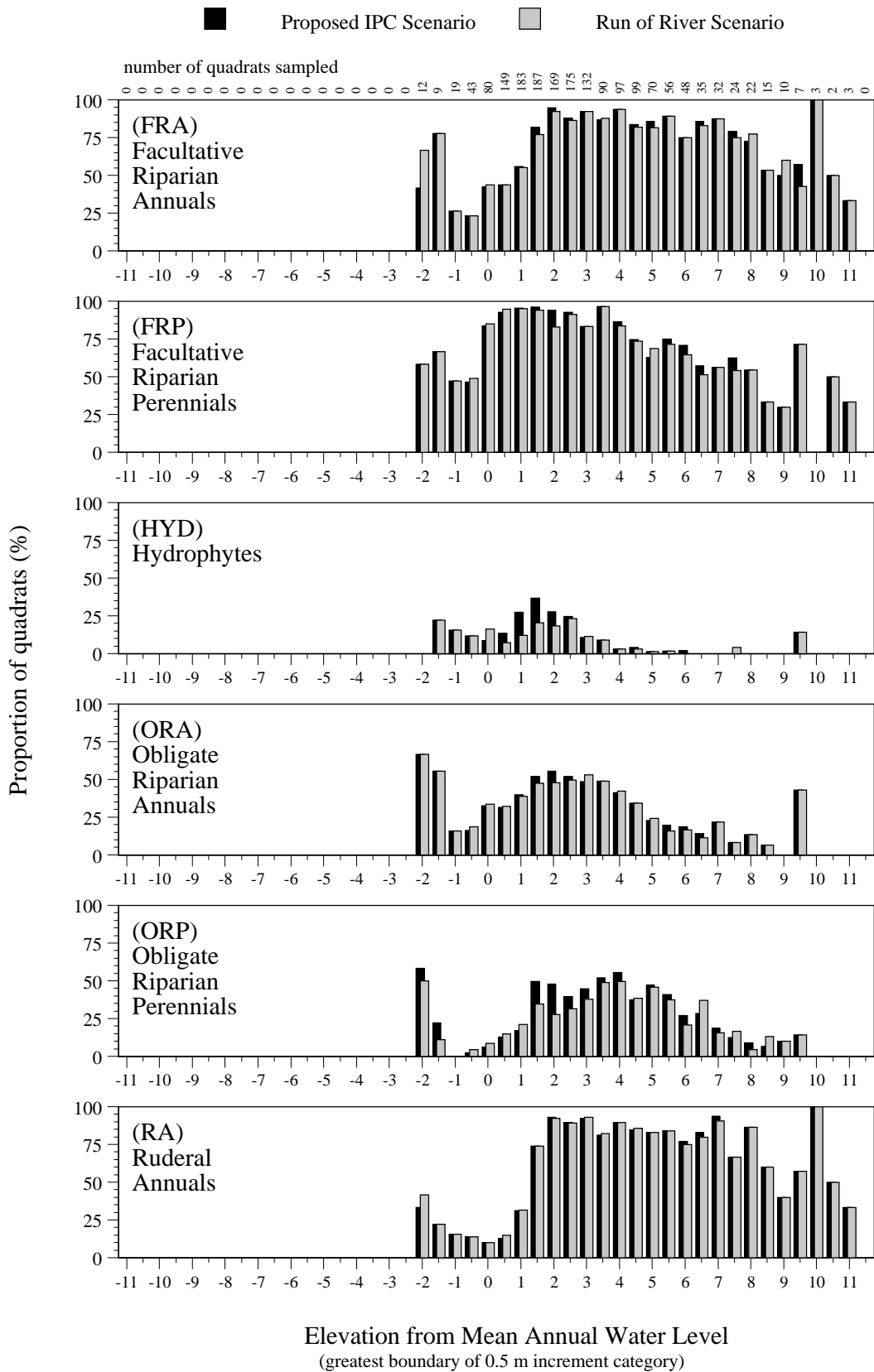


Figure 3.22. Sum of proportions of quadrats along the Snake River Reach (SN) that are occupied by each vegetation group according to the Proposed IPC and Run of River scenarios at year 100. The value above each bar indicates the percent difference relative to the Run of River Scenario. Quadrats at elevations > 9 m or < -1 m from the mean annual water level were omitted. (FRA = Facultative Riparian Annuals, FRP = Facultative Riparian Perennials, HYD = Hydrophytes, ORA = Obligate Riparian Annuals, ORP = Obligate Riparian Perennials, RA = Ruderal Annuals)

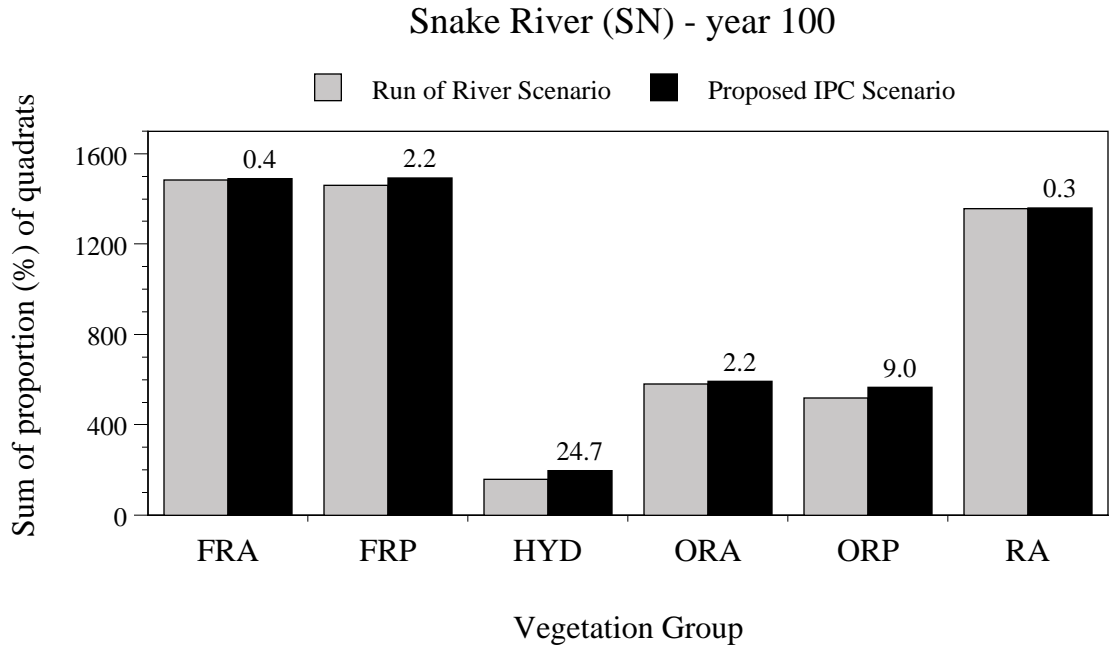


Figure 3.23. Average elevation versus average number of years since establishment for quadrats along the Snake River reach (SN) that are occupied by each vegetation group at year 110 according to the Run of River and Proposed IPC scenarios (bars indicate +/- 1 SD).

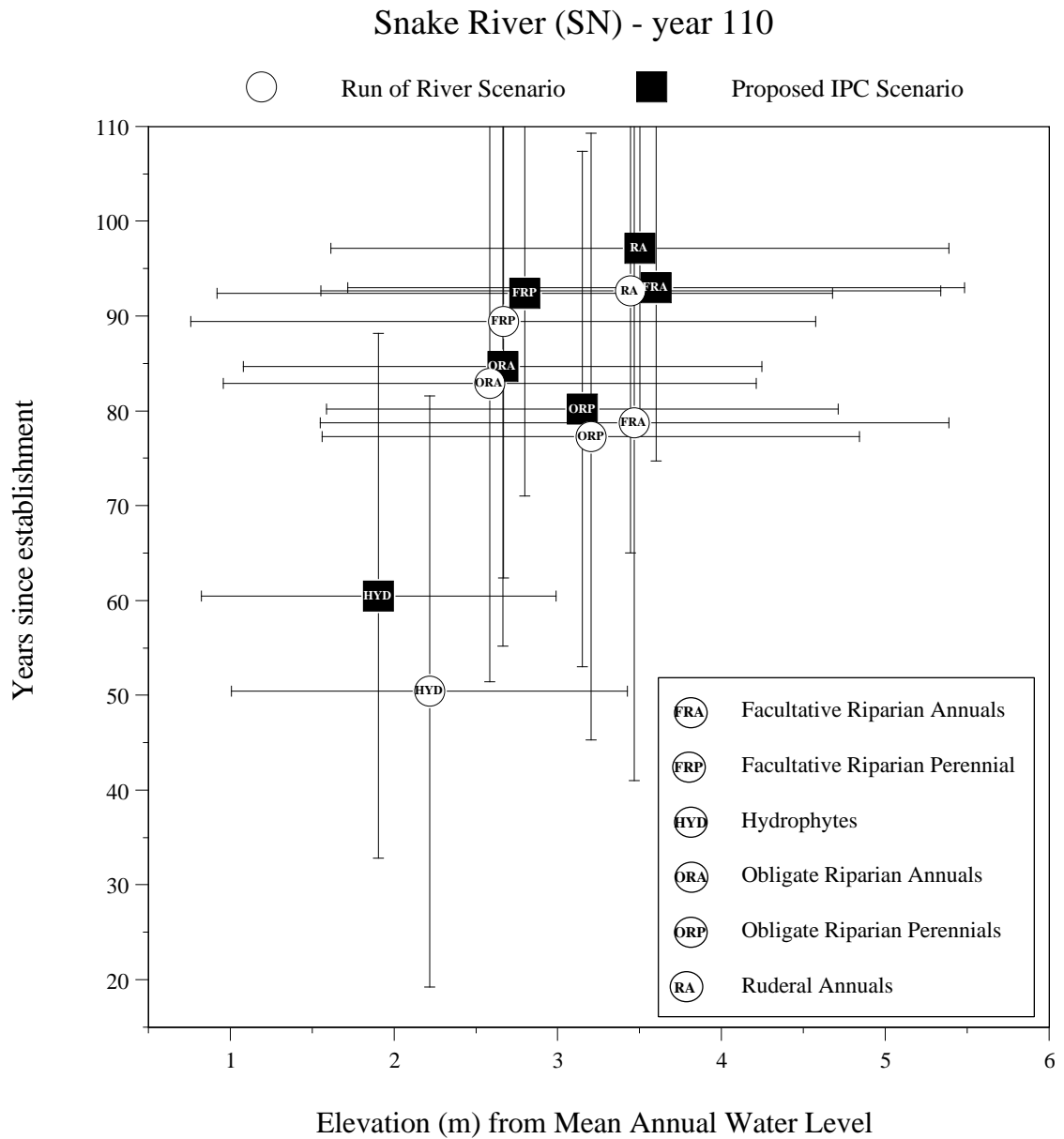
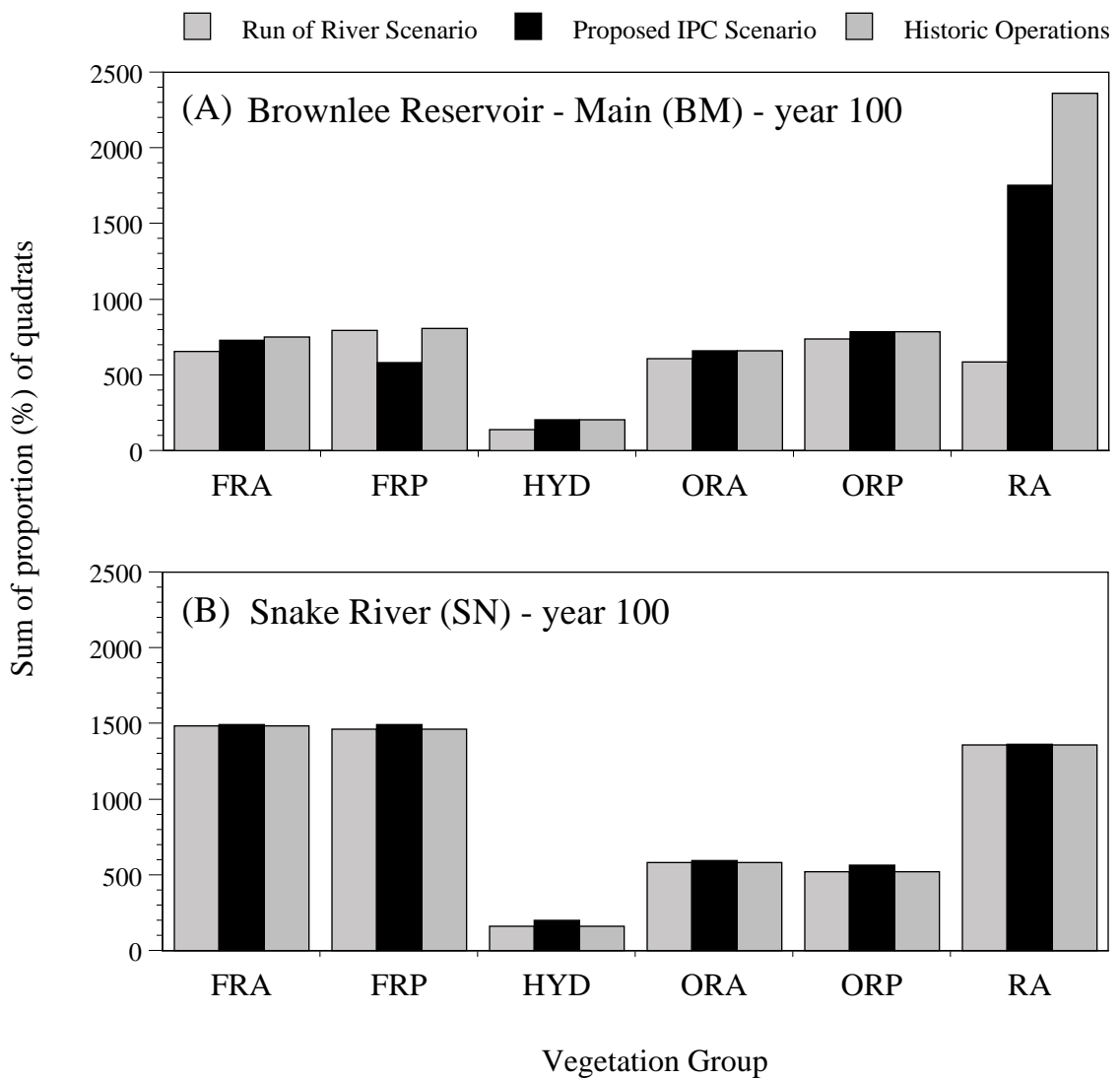


Figure 3.24. Sum of proportions of quadrats along the Brownlee Reservoir - Main (BM) and Snake River Reach (SN) that are occupied by each vegetation group according to the Proposed IPC, Run of River, and Historic Operations scenarios at year 100. (FRA = Facultative Riparian Annuals, FRP = Facultative Riparian Perennials, HYD = Hydrophytes, ORA = Obligate Riparian Annuals, ORP = Obligate Riparian Perennials, RA = Ruderal Annuals)



Appendix 3.1. Names and abbreviations for the 195 species along the reservoir and Snake River reaches (all non-vascular species and species that were incompletely classified have been omitted).

| Abbreviations: | | | | | | |
|-----------------------|----------------------|------|----------------------------------|-----|--------------------------------|--|
| | Veg. Class | | Status | | Veg. Group | |
| AG | Annual Grass | N | Native | FRA | Facultative Riparian Annual | |
| AH | Annual Herb | E | Exotic | FRP | Facultative Riparian Perennial | |
| PG | Perennial Grass | NOX | Noxious | HYD | Hydrophyte | |
| PH | Perennial Herb | TES | Threatened or Endangered Species | ORA | Obligate Riparian Annual | |
| WS | Woody Shrub | | | ORP | Obligate Riparian Perennial | |
| WSS | Woody Shrub Seedling | | | RA | Ruderal Annual | |
| WT | Woody Tree | Res | reservoirs | UPA | Upland Annual | |
| WTS | Woody Tree Seedling | Riv | Snake River reach | UPP | Upland Perennial | |
| | | both | reservoirs & Snake River reach | | | |

| Areas where present | Species Code | Scientific Name | Common Name | Veg. Class | Status | Veg. Group |
|----------------------------|---------------------|-------------------------------------|------------------------------------|-------------------|---------------|-------------------|
| both | ACMI | <i>Achillea millefolium</i> | western yarrow | PH | N | UPP |
| both | ACSA | <i>Acer saccharinum</i> | silver maple | WT | E | FRP |
| Res | ACSA5 | <i>Acer saccharinum</i> (seedling) | silver maple (seedling) | WTS | E | FRP |
| Res | AGRE | <i>Agropyron repens</i> | quackgrass | PG | NOX | UPP |
| Riv | AGRO | <i>Agrostis spp</i> | bentgrass | PG | x | UPP |
| both | AGSP | <i>Agropyron spicatum</i> | bluebunch wheatgrass | PG | N | UPP |
| both | AGUR | <i>Agastache urticifolia</i> | horse mint | PH | N | FRP |
| both | ALRH | <i>Alnus rhombifolia</i> | white alder | WT | N | FRP |
| Res | ALRH5 | <i>Alnus rhombifolia</i> (seedling) | white alder (seedling) | WTS | N | FRP |
| both | AMAL | <i>Amaranthus albus</i> | tumble pigweed | AH | E | RA |
| both | AMAL2 | <i>Amelanchier alnifolia</i> | Western serviceberry | WS | N | UPP |
| both | AMAR | <i>Ambrosia artemisiifolia</i> | common ragweed | AH | NOX | RA |
| Res | AMFR | <i>Amorpha fruticosa</i> | false indigo | WT | E | ORP |
| Res | AMFR5 | <i>Amorpha fruticosa</i> (seedling) | false indigo (seedling) | WTS | E | ORP |
| both | AMPA | <i>Amaranthus palmeri</i> | Palmer amaranth / carelessnessweed | AH | E | RA |
| both | AMRE | <i>Amaranthus retroflexus</i> | redroot pigweed | AH | E | RA |
| Res | ANCA | <i>Anthriscus caucalis</i> | burchervil | AH | E | RA |
| Res | ANCO | <i>Anthemis cotula</i> | Mayweed chamomile | AH | E | RA |
| both | ANMI | <i>Antennaria microphylla</i> | rosy pussy-toes | PH | N | UPP |
| both | APAN | <i>Apocynum androsaemifolia</i> | spreading dogbane | PH | N | FRP |
| both | APCA | <i>Apocynum cannabinum</i> | hemp Dogbane | PH | N | FRP |
| Riv | ARLI | <i>Artemisia lindleyana</i> | Columbia R. mugwort | PH | N | FRP |
| Riv | ARLO | <i>Aristida longiseta</i> | Red three-awn | PG | N | UPP |
| both | ARLU | <i>Artemisia ludoviciana</i> | Western mugwort | PH | N | FRP |
| Res | ARMI | <i>Arctium minus</i> | common burdock | BH | E | UPP |
| both | ARTR | <i>Artemisia tridentata</i> | big sagebrush | WS | N | UPP |
| Riv | ASEA | <i>Aster eatonii</i> | Easton's aster | PH | N | FRP |
| Riv | ASFR | <i>Asclepias fascicularis</i> | narrow-lvd milkweed | PH | N | FRP |
| Riv | ASOC | <i>Aster occidentalis</i> | western mountain aster | PH | N | UPP |
| both | ASSP | <i>Asclepias speciosa</i> | showy milkweed | PH | N | FRP |
| Res | ATRO | <i>Atriplex rosea</i> | red orache | AH | E | RA |
| Riv | AVFA | <i>Avena fatua</i> | wild oat | AG | E | UPA |
| Res | AZME | <i>Azolla mexicana</i> | water fern | AH | N | HYD |
| Res | BASA | <i>Balsamorhiza sagittata</i> | balsam-root | PH | N | UPP |
| Res | BOSI | <i>Botrychium simplex</i> | little grape-fern | PH | N | UPP |
| Res | BRJA | <i>Bromus japonicus</i> | Japanese brome | AG | E | UPA |
| Res | BRKA | <i>Brassica kaber</i> | wild mustard | AH | E | UPP |
| both | BRST | <i>Bromus sterilis</i> | barren brome | AG | E | UPA |
| both | BRTE | <i>Bromus tectorum</i> | cheatgrass | AG | E | UPA |

Appendix 3.1. (Cont.)

| Areas where present | Species Code | Scientific Name | Common Name | Veg. Class | Status | Veg. Group |
|---------------------|--------------|-------------------------------------|-------------------------------|------------|--------|------------|
| Res | CACO | <i>Cardamine cordifolia</i> | heart-leaved bittercress | PH | N | FRP |
| Res | CADR | <i>Cardaria draba</i> | white-top / hoary cress | PH | NOX | UPP |
| Riv | CASP | <i>Calamagrostis spp.</i> | bunch grass | PG | x | UPP |
| both | CAVU | <i>Carex vulpinoidea</i> | fox sedge | PH | E | ORP |
| Riv | CELO | <i>Cenchrus longispinus</i> | Sandbur | AG | E | RA |
| Riv | CEMA | <i>Cercocarpus macrourus</i> | Mountain mahogany | WS | N | UPP |
| both | CERE | <i>Celtis reticulata</i> | netleaf hackberry | WT | N | FRP |
| both | CERE5 | <i>Celtis reticulata</i> (seedling) | netleaf hackberry (seedling) | WTS | N | FRP |
| Riv | CESO | <i>Centaurea solstitialis</i> | yellow star thistle | AH | E | RA |
| Res | CHAL | <i>Chenopodium album</i> | white goosefoot/lambsquarters | AH | E | RA |
| Res | CHBE | <i>Chenopodium berlandieri</i> | netseed lambsquarters | AH | E | RA |
| Res | CHMU | <i>Chenopodium murale</i> | nettleleaf goosefoot | AH | E | RA |
| both | CHNA | <i>Chrysothamnus nauseosus</i> | gray rabbitbrush | PH | N | UPP |
| both | CHVI | <i>Chrysopsis villosa hispida</i> | hairy golden aster | PH | N | FRP |
| both | CIAR | <i>Cirsium arvense</i> | Canada thistle | PH | NOX | UPP |
| Res | CIDO | <i>Cicuta douglasii</i> | water hemlock | PH | N | ORP |
| both | CIIN | <i>Cichorium intybus</i> | chicory | PH | E | UPP |
| both | CLLI | <i>Clematis ligusticifolia</i> | western clematis | PH | N | UPP |
| both | COAR | <i>Convolvulus arvensis</i> | field morning-glory | PH | NOX | UPP |
| both | COCA | <i>Conyza canadensis</i> | horseweed | AH | E | RA |
| both | COMA | <i>Conium maculatum</i> | poison hemlock | BH | NOX | FRP |
| both | COST | <i>Cornus stolonifera</i> | red-osier dogwood | WS | N | FRP |
| Res | CRDO | <i>Crataegus douglasii</i> | hawthorn | WS | N | UPP |
| both | CROC | <i>Crepis occidentalis</i> | western hawksbeard | PH | E | UPP |
| Res | CRYP | <i>Cryptantha spp</i> | cryptantha | PH | x | UPP |
| Res | CYAR | <i>Cyperus aristatus</i> | short-pointed flatsedge | AH | N | ORP |
| Riv | CYDA | <i>Cynodon dactylon</i> | bermudagrass | PG | E | UPP |
| both | CYER | <i>Cyperus erthyrorrhizos</i> | red-rooted flatsedge | AH | N | ORP |
| both | CYES | <i>Cyperus esculentus</i> | yellow nut sedge | PH | NOX | ORP |
| both | CYOF | <i>Cynoglossum officinale</i> | houndstongue | BH | NOX | UPP |
| Riv | CYSC | <i>Cyperus schweinitzii</i> | Schweinitz flatsedge | PH | TES | FRP |
| Res | DAGL | <i>Dactylis glomerata</i> | orchardgrass | PG | E | UPP |
| both | DISA | <i>Digitaria sanguinalis</i> | large crabgrass | AG | E | RA |
| both | DISY | <i>Dipsacus sylvestris</i> | teasel | BH | E | UPP |
| both | ECCR | <i>Echinochola crus-galli</i> | barnyard grass | AG | E | RA |
| Riv | EESP | <i>Erigeron spp</i> | | PH | x | UPP |
| Res | ELAN | <i>Elaeagnus angustifolia</i> | Russian-olive | WT | E | FRP |
| Res | ELCI | <i>Elymus cinereus</i> | giant wildrye | PG | N | UPP |
| Res | ELEO | <i>Eleocharis spp.</i> | spike rush | PH | N | ORP |
| Res | EPGL | <i>Epilobium glaberrinum</i> | smooth willow-herb | PH | N | FRP |
| Res | EPMI | <i>Epilobium minutum</i> | small-flowered willow-herb | AH | N | RA |
| both | EPPA | <i>Epilobium paniculatum</i> | autumn willow-herb | AH | N | RA |
| both | EQLA | <i>Equisetum laevigatum</i> | smooth scouring-rush | PH | N | ORP |
| Riv | ERCI | <i>Eragrostis cilianensis</i> | Stinkgrass | AG | E | FRA |
| both | ERCO | <i>Eriogonum compositum</i> | northern buckwheat | PH | N | UPP |
| Riv | ERIG | <i>Eriogonum spp.</i> | | PH | x | UPP |
| Res | ERNI | <i>Eriogonum niveum</i> | snow buckwheat | PH | N | UPP |
| Res | EUES | <i>Euphorbia esula</i> | leafy spurge | PH | NOX | UPP |
| both | EUGL | <i>Euphorbia glyptosperma</i> | corrugate-seeded spurge | AH | N | ORA |
| both | EUSE | <i>Euphorbia serpyllifolia</i> | thyme-leaved spurge | AH | N | RA |
| Res | FEOC | <i>Festuca octoflora</i> | six-weeks fescue | AG | N | RA |
| both | FRPE | <i>Fraxinus pennsylvanica</i> | ash | WT | E | FRP |
| both | GAPA | <i>Gaura parviflora</i> | velvety gaura | AH | E | RA |
| Riv | GLLE | <i>Glycyrrhiza lepidota</i> | American licorice | PH | N | FRP |
| Res | GNPA | <i>Gnaphalium palustre</i> | lowland cudweed | AH | N | UPA |

Appendix 3.1. (Cont.)

| Areas where present | Species Code | Scientific Name | Common Name | Veg. Class | Status | Veg. Group |
|---------------------|--------------|-----------------------------------|-------------------------------|------------|--------|------------|
| both | GRSQ | <i>Grindelia squarrosa</i> | curly-cup gumweed | PH | N | UPP |
| Res | GUSA | <i>Gutierrezia sarothrae</i> | broom snakeweed | PH | N | UPP |
| Riv | HAPL | <i>Haplopappus spp.</i> | | PH | x | UPP |
| Res | HEAL | <i>Heleochloa alopecuroides</i> | heleochloa | AG | E | ORA |
| both | HEAN | <i>Helianthus annuus</i> | common sunflower | AH | N | FRA |
| both | HEAU | <i>Helenium autumnale</i> | mountain sneeze weed | PH | N | FRP |
| Res | HOLA | <i>Holcus lanatus</i> | common velvet-grass | PG | E | FRP |
| both | HYPE | <i>Hypericum perforatum</i> | common St. Johns Wort | PH | NOX | UPP |
| both | IRPS | <i>Iris pseudoacorus</i> | yellow iris / yellow-flag | PH | E | HYD |
| Res | IVAX | <i>Iva axillaris</i> | poverty sumpweed | PH | N | UPP |
| both | JUNC | <i>Juncus spp.</i> | rush species | PH | N | ORP |
| Res | JURE | <i>Juglans regia</i> | common walnut | WT | E | UPP |
| both | LASE | <i>Lactuca serriola</i> | prickly lettuce | AH | E | UPP |
| both | LELA | <i>Lepidium latifolium</i> | perennial pepperweed | PH | NOX | FRP |
| Res | LEPE | <i>Lepidium perfoliatum</i> | clasping pepperweed | AH | E | RA |
| Res | LIGE | <i>Linaria genistifolia</i> | dalmation toadflax | PH | NOX | UPP |
| both | LOPU | <i>Lotus purshiana</i> | spanish clover | AH | N | UPA |
| Res | LYAM | <i>Lycopus americanus</i> | cut-leaved water horehound | PH | N | ORP |
| both | LYSA | <i>Lythrum salicaria</i> | purple loosestrife | PH | NOX | ORP |
| Res | MEAR | <i>Mentha arvensis</i> | field mint | PH | E | FRP |
| Res | MELU | <i>Mentzelia laevicaulis</i> | blazing star | BH | N | UPP |
| both | MEOF | <i>Melilotus officinalis</i> | yellow sweetclover | AH | E | FRA |
| Res | MESA | <i>Medicago sativa</i> | alfalfa | PH | E | UPP |
| both | MOVE | <i>Mollugo verticillata</i> | carpetweed | AH | N | FRA |
| Res | NECA | <i>Nepeta cataria</i> | catnip | PH | E | FRP |
| both | ONAC | <i>Onopordum acanthium</i> | Scotch thistle | BH | NOX | UPP |
| Riv | OPPO | <i>Opuntia polyacantha</i> | prickly pear cactus | PH | N | UPP |
| both | PACA | <i>Panicum capillare</i> | common witchgrass | AG | E | RA |
| Res | PADI | <i>Paspalum distichum</i> | knotgrass | PG | E | FRP |
| both | PHAR | <i>Phalaris arundinacea</i> | reed canarygrass | PG | N | ORP |
| both | PHLE | <i>Philadelphus lewisii</i> | Syringa / mock orange | WS | N | FRP |
| both | PHLO | <i>Physalis longifolia</i> | long-leaved ground cherry | PH | E | FRP |
| both | PIPO | <i>Pinus ponderosa</i> | Ponderosa pine | WT | N | UPP |
| Riv | PIPO5 | <i>Pinus ponderosa</i> (seedling) | Ponderosa Pine (seedling) | WTS | N | UPP |
| both | PLLA | <i>Plantago lanceolata</i> | buckhorn plantain | PH | E | UPP |
| Res | PLMA | <i>Plantago major</i> | broadleaf plantain | PH | E | FRP |
| Riv | PLPA | <i>Plantago patagonica</i> | wooly plantain | AH | N | RA |
| both | POAM | <i>Polygonum amphibium</i> | Water smartweed | PH | N | HYD |
| both | POAN | <i>Poa annua</i> | annual bluegrass | AG | E | RA |
| both | POAV | <i>Polygonum aviculare</i> | prostrate knotweed | AH | E | FRA |
| Res | POBU | <i>Poa bulbosa</i> | bulbous bluegrass | PG | E | UPP |
| Riv | POCO | <i>Polygonum coccineum</i> | Water smartweed | PH | N | HYD |
| both | PODE | <i>Populus deltoides</i> | plains cottonwood | WT | E | FRP |
| both | POER | <i>Polygonum erectum</i> | erect knotweed | AH | E | RA |
| Res | POLA | <i>Polygonum lapathifolium</i> | pale smartweed | AH | N | RA |
| both | POMO | <i>Polypogon monspeliensis</i> | rabbit foot polypogon | AG | E | ORA |
| both | POOL | <i>Portulaca oleracea</i> | purselane | AH | E | RA |
| Res | POP5 | <i>Populus spp.</i> (seedling) | Poplar species (seedling) | WTS | N | FRP |
| both | POPE | <i>Polygonum persicaria</i> | spotted ladythumb | AH | E | ORA |
| Res | POPR | <i>Poa pratensis</i> | Kentucky blue grass | PG | E | UPP |
| Res | PORI | <i>Potentilla rivalis</i> | river potentilla / cinquefoil | AH | N | ORA |
| Res | POSE | <i>Poa secunda</i> | Sandberg's bluegrass | PG | N | UPP |
| Riv | POTR | <i>Populus trichocarpa</i> | black cottonwood | WT | N | FRP |
| Riv | PRVI | <i>Prunus virginiana</i> | chokecherry | WT | N | FRP |
| Res | PUTR | <i>Purshia tridentata</i> | antelope bush / bitter brush | WS | N | UPP |

Appendix 3.1. (Cont.)

| Areas where present | Species Code | Scientific Name | Common Name | Veg. Class | Status | Veg. Group |
|---------------------|--------------|---|-------------------------------|------------|--------|------------|
| Riv | RHGL | <i>Rhus glabra</i> | Sumac | WS | N | UPP |
| both | RHPU | <i>Rhamnus purshiana</i> | casacara | WS | N | FRP |
| Res | ROPS | <i>Robinia pseudoacacia</i> | black locust | WT | E | UPP |
| both | ROWO | <i>Rosa woodsii</i> | wood rose | WS | N | UPP |
| Res | RUAC | <i>Rumex acetosella</i> | red sorrel | PH | E | UPP |
| both | RUCR | <i>Rumex crispus</i> | curly dock | PH | E | FRP |
| Res | RUDI | <i>Rubus discolor</i> | Himalayan blackberry | WS | E | FRP |
| Res | SAAL | <i>Salix alba</i> | European white willow | WT | E | ORP |
| both | SAEX | <i>Salix exigua</i> | coyote/sandbar willow | WS | N | ORP |
| both | SAIB | <i>Salsola iberica</i> | Russian thistle | AH | E | RA |
| both | SALA | <i>Salix lasiandra</i> | Pacific willow | WS | N | ORP |
| Res | SALA2 | <i>Sagittaria latifolia</i> | arrowleaf/wapato | PH | N | HYD |
| both | SALX5 | <i>Salix spp.</i> (seedling) | willow species (seedling) | WSS | N | ORP |
| both | SAOF | <i>Saponaria officinalis</i> | bouncingbet / soapwort | PH | E | UPP |
| Res | SARA | <i>Sambucus racemosa</i> | black elderberry | WS | N | FRP |
| both | SCAC | <i>Scirpus acutus</i> | common bulrush | PH | N | HYD |
| Res | SEGL | <i>Setaria glauca</i> | yellow foxtail grass | AG | E | RA |
| both | SEVI | <i>Setaria viridis</i> | green bristlegrass | AG | E | RA |
| Res | SIHE | <i>Sida hederacea</i> | alkali sida | PH | N | UPP |
| Res | SMRA | <i>Smilacina racemosa</i> | false solomon seal | PH | N | FRP |
| Res | SOCA | <i>Solidago canadensis</i> | meadow goldenrod | PH | N | UPP |
| Res | SODU | <i>Solanum dulcamara</i> | bittersweet nightshade | PH | E | FRP |
| Res | SOOC | <i>Solidago occidentalis</i> | Western goldenrod | PH | N | UPP |
| both | SPCR | <i>Sporobolus cryptandrus</i> | sand dropseed | PG | N | UPP |
| Riv | SPPE | <i>Spartina pectinata</i> | Prairie cordgrass | PG | N | ORP |
| both | STOC | <i>Stipa occidentalis</i> | needle and thread | PG | N | UPP |
| both | TACA | <i>Taeniatherum caput-medusae</i> | medusahead wildrye | AG | NOX | UPP |
| Res | TAOF | <i>Taraxacum officinale</i> | dandelion | PH | E | UPP |
| both | TARA | <i>Tamarix ramosissima</i> + <i>T. parviflora</i> | salt cedar complex | WT | E | ORP |
| Res | TARA5 | <i>Tamarix</i> (seedling) | salt cedar complex (seedling) | WTS | E | ORP |
| Res | TAVU | <i>Tanacetum vulgare</i> | common tansy | PH | E | FRP |
| both | TORA | <i>Toxicodendron radicans</i> | poison-ivy | WS | N | FRP |
| Riv | TORA5 | <i>Toxicodendron radicans</i> (seedling) | poison-ivy (seedling) | WSS | N | FRP |
| both | TRDU | <i>Tragopogon dubius</i> | western salsify (goatsbeard) | BH | E | UPP |
| both | TRTE | <i>Tribulus terrestris</i> | puncture vine | AH | NOX | RA |
| Res | TYLA | <i>Typha latifolia</i> | cattail | PH | N | HYD |
| both | ULAM | <i>Ulmus americana</i> | American elm | WT | E | FRP |
| Res | ULPA | <i>Ulmus parvifolia</i> | Chinese elm | WT | E | FRP |
| Res | ULPU | <i>Ulmus pumila</i> | Siberian elm | WT | E | FRP |
| Res | URDI | <i>Urtica dioica</i> | stinging nettle | PH | N | FRP |
| Res | VEAM | <i>Veronica anagallis-aquatica</i> | water speedwell | PH | E | ORP |
| both | VEBL | <i>Verbascum blattaria</i> | moth mullein | BH | E | UPP |
| both | VEBR | <i>Verbena bracteata</i> | bracted mullein | BH | E | UPP |
| both | VETH | <i>Verbascum thapsus</i> | common mullein | BH | E | UPP |
| both | VUMY | <i>Vulpia myuros</i> | rattail fescue | AG | E | RA |
| both | XAST | <i>Xanthium strumarium</i> | common cocklebur | AH | N | RA |

Appendix 3.2. Life Histories of Select Plant Series.

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Introduction

During the latter portion of the 1998 growing season, sampling of riparian and shoreline vegetation was initiated to quantify patterns of vascular plant distribution in relation to current/historic flow regimes along the IPC study corridor. An initial set of permanent cross-sectional transects was established along each study reach, including Brownlee, Oxbow and Hells Canyon reservoirs and Snake River/Hells Canyon Corridor. These transects represent our initial sampling effort to capture the range of vegetation patterns that are representative of riparian and shoreline habitats within the IPC Hells Canyon Study Corridor.

The vegetation structure and diversity observed along the river reach was relatively low. A few black cottonwoods (*Populus trichocarpa*) were found along the Snake River near Wieser and below the Hells Canyon dam where they were usually associated with relatively large floodplains and perennial tributaries. Hackberry (*Celtis reticulata*), and sandbar willow (*Salix exigua*) were the most common woody plants in obligate and transitional riparian zones. These species tended to be distributed as non-contiguous bands of vegetation along riverbanks. A common herbaceous species within obligate and transitional zones was water smartweed (*Polygonum amphibium*).

The vegetation structure and diversity observed along reservoir shorelines was also low. As the reservoir fringe is a recently established artificial habitat, Eurasian species including some noxious weeds were common in our study plots. Some commonly encountered herbaceous species included common cocklebur (*Xanthium strumarium*), common licorice (*Glycyrrhiza lepidota*), false indigo (*Amorpha fruticosa*), and salt cedar (*Tamarix ramosissima*) populations that appear to be rapidly expanding (300 to 1400 seedlings/m²) along the Weiser reach (below Porters Ferry).

Summaries of the individual plant species

A summary of the life histories of the above mentioned plant species follows, in the general order of the most desirable trees, shrubs, and herbs to the least desirable invasive, introduced weeds. Note that hackberry, willow, and cottonwood are all very desirable species and thus, they are listed according to abundance along the Snake River.

Hackberry (*Celtis reticulata*) is a drought tolerant, widely distributed species that occupies riparian habitats along high water lines (Salzer et al. 1996) in the semiarid regions of the western United States. Hackberry establishment is often associated with surface rock or rock outcrops and trees typically have a lifespan of 60 years but may live as long as 300 years (Debolt and McCune 1995). Although populations tend to be small or highly localized, hackberry provides cover for big game species and livestock (Debolt and McCune 1995). The fall ripening fruit that often persists on the branches until winter (Bonner 1974) also provides food for a variety of birds and mammals (Debolt and McCune 1995). Despite disturbance from grazing and harvesting, populations in Idaho are generally maintaining themselves (DeBolt and McCune 1995).

Sandbar willow (*Salix exigua*) is a native, obligate phreatophyte that is highly tolerant of flooding (Shaw 1991) and is restricted to mesic habitats where there is a constant water table throughout much of the year (Cleverly et al. 1997). Common along alluvial bars throughout most

of North America, sandbar willow spreads extensively by ramet (asexual) reproduction (Ottenbreit and Staniforth 1992). A summer-disperser (Densmore and Zasada 1983), sandbar willow may establish more successfully than salt cedar during wet years or in early successional communities (Cleverly et al. 1997).

Black cottonwood (*Populus trichocarpa*) is native to North America and is often the dominant species in riparian habitats where it provides shelter for wildlife, and streambank protection. The life history of cottonwoods is closely related to streamflow particularly because sexual (seedling) establishment by the species is dependent on high streamflow events and the survival of this phreatophyte (obtains water from saturated soils) depends on gradual, constant streamflow reduction. Asexual reproduction of black cottonwoods is also common and is primarily promoted by crown removal. Cottonwood populations have greatly declined in the southwestern United States particularly as a result of water diversion from streams, onstream reservoirs, channelization, agricultural clearing, exotic plant invasions and livestock grazing. Much literature exists on the life history of the black cottonwood and a summary chapter by Braatne et al. (1996) contains most of the pertinent information.

Water smartweed (*Polygonum amphibium*) is a native (Mitchell 1976), semiaquatic species that is very flood tolerant (Carter and Grace 1990). Smartweed is a perennial that reproduces both sexually and asexually around lake and pond shores where it provides food and cover for waterfowl and fish (Justice 1944).

Common licorice (*Glycyrrhiza lepidota*) is a native perennial legume that is common in disturbed areas where it has the potential to vigorously reproduce asexually (Boe and Wynia 1985). Much of the current literature focuses on the species' medicinal uses and little literature exists on the plant's life history. However, licorice plants have been recognized for their soil binding capabilities and for their potential as highly digestible forage (Boe and Wynia 1985).

Common cocklebur (*Xanthium strumarium*) has two subspecies, one that is native to Mediterranean-Eurasia and the other to America (Weaver and Lechowicz 1983). It grows best with a water table that is 5 to 90 cm below the soil surface and tolerates flooding at all stages of growth (Weaver and Lechowicz 1983). It is common at latitudes from 53°N to 33°S along disturbed shorelines of sandy rivers (Blais and Lechowicz 1989). Cocklebur will not tolerate shading and only reproduces by seed, often inbreeding, in soils with some nitrogen and a high moisture content (Weaver and Lechowicz 1983). Seeds are easily dispersed by streams because the burs remain buoyant for up to 30 days (Weaver and Lechowicz 1983). Cocklebur will tolerate saline soils (Weaver and Lechowicz 1983). The plant is a nuisance because, although the vegetative growth of the mature plant may provide nutritious forage, the seeds and young seedlings are poisonous to livestock (Weaver and Lechowicz 1983).

False indigo (*Amorpha fruticosa*) is native to the mid-western United States (Lapin and Nothnagle 1995) and widely distributed (Palmer 1931). False indigo may become dominant in riparian areas and can reproduce asexually following flood disturbance (Lapin and Nothnagle 1995). It is interesting to note that the Nature Conservancy has tried to remove this plant from riparian areas along the Connecticut River to provide habitat for an endangered and threatened beetle (Lapin and Nothnagle 1995).

Salt cedar (*Tamarix ramosissima*) is an exotic Asian species (Manning et al. 1996) introduced as an ornamental shrub to the United States in the 1800's (Gladwin and Roelle 1998). Salt cedar escaped cultivation in the 1870's and had infested at least 600,000 ha of riparian habitat in the southwestern United States by 1987 (Di Tomaso 1998). Salt cedar can be classified as a phreatophyte although it may also use water from the unsaturated zone (Busch and Smith 1995). While mature salt cedar plants can survive complete submergence for as long as 70 days or complete, long-term watercourse desiccation (Cleverly et al. 1997), seedling survival requires at least 4 to 6 weeks without inundation (Di Tomaso 1998). Invasion of salt cedar in the southwestern United States has:

- 1) led to an apparent increase in riparian ecosystem fires because of its flammable leaf litter (Busch and Smith 1993)
- 2) affected natural river flows, desiccated floodplains, and lowered water tables (Cleverly et al. 1997)
- 3) led to a monoculture community and resulted in the loss of many vertebrate and bird species (Gladwin and Roelle 1998)
- 4) displaced native cottonwoods and willows (Gladwin and Roelle 1998) and has been detrimental to native vegetation, wetlands, and aquatic fauna (Manning et al. 1996)
- 5) increased soil salt levels that disfavor native cottonwood and willow seedling recruitment but permit salt cedar seedling establishment (Sala et al 1996).

Salt cedar reproduces both sexually and asexually and mature saltcellar is tolerant to cutting, grazing, burning, heat, cold, and high concentrations of dissolved solids (Di Tomaso 1998). Much literature exists on the life history of salt cedar and is compiled in Di Tomaso (1998).

Comparisons of habitats across species

A literature search was conducted to summarize the life histories of the plant species. The information gathered, particularly on phenology and habitat requirements, will aid in predicting future responses of these species to various operational scenarios. Figure 1 shows the establishment sites that are favored by the species in relation to water requirements. Due to a lack of literature, common licorice was not included in this figure. However, during our field observations, it was noted that licorice commonly extended from highwater mark to the late summer stream stage elevation on the Brownlee and Oxbow reservoirs. Figure 2 attempts to describe the phenology of the plant species, although a lack of literature once again precludes completeness. Extensive information in point form follows for each plant species in alphabetical order by genus with the source of reference and page location for each description.

Figure 1. Preferred establishment sites for *Amorpha fruticosa* (Amfr), *Celtis reticulata* (Cere), *Polygonum amphibium* (Poam), *Populus trichocarpa* (Potr), *Salix exigua* (Saex), *Tamarix ramosissima* (Tara) and *Xanthium strumarium* (Xast). The drought tolerance of *X. strumarium* is unknown.

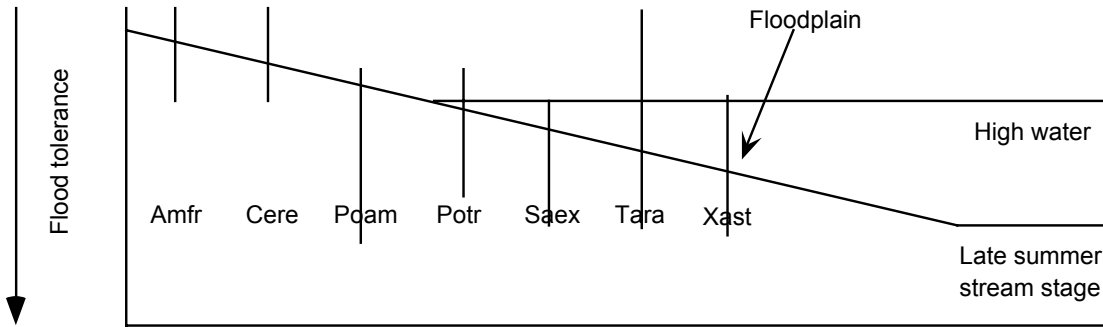
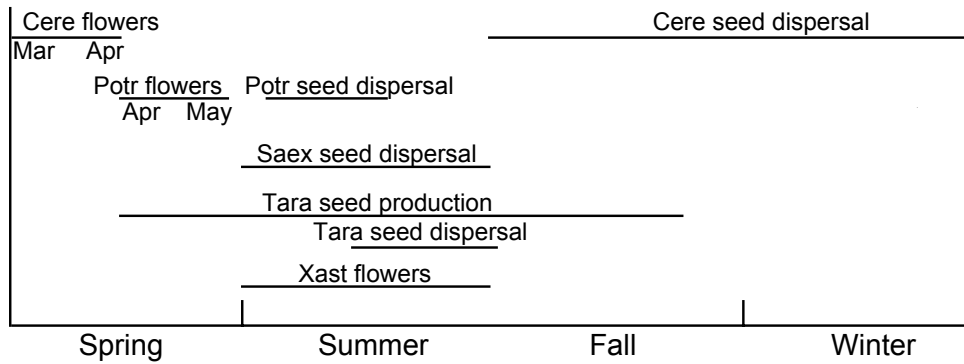


Figure 2. Phenology of some characteristics for *Celtis reticulata* (Cere), *Populus trichocarpa* (Potr), *Salix exigua* (Saex), *Tamarix ramosissima* (Tara) and *Xanthium strumarium* (Xast).



Life History of *Amorpha fruticosa*

Family: Fabaceae (Legume) Tribe: Psoraleae

Common names: False indigo

Background

Description:

- low shrub of clumped stems up to 5 m tall (Lapin and Nothnagle 1995)

Classification:

- difficult to distinguish *Amorpha fruticosa* from closely related species (Palmer 1931)
- many forms are named based on cultivated varieties (Palmer 1931)

Range:

- temperate and semi-tropical parts of North America (Palmer 1931)
- native to the southeastern and mid-western United States, from Pennsylvania south to Florida and west to Ohio, Michigan, Wisconsin, and Kansas (Lapin and Nothnagle 1995)
- widely distributed over most of United States east of the Rocky Mountains, from Canada to Florida and beyond the Rio Grande into northern Mexico (Palmer 1931)
- naturalized in the northeastern United States, Europe and western Asia (Palmer 1931)

Uses/Value:

- cultivated since the 18th century (Palmer 1931) and has escaped to New England and New York (Fernald 1959—cited in Lapin and Nothnagle 1995)

Growth

Preferences:

- often found above high tide line of freshwater tidal areas and associated beaches along the Connecticut River and can become dominant in riparian areas (Lapin and Nothnagle 1995)

Control:

- Nature Conservancy used roundup to remove "non-native" plants of *A. fruticosa* from riparian areas in Connecticut to provide habitat for the endangered and threatened Puritan tiger beetle (Lapin and Nothnagle 1995)
- a reliable control method has not been reported, although foliar application of 18% Roundup was successful in its control (Lapin and Nothnagle 1995)

Reproduction

Sexual:

- impermeable seed coat and high percentage of dormant seed results in delayed natural germination (Lapin and Nothnagle 1995)

Asexual:

- predominantly clonal, from stems and roots following floods (Lapin and Nothnagle 1995)
- cut stems produce multiple resprouts (Lapin and Nothnagle 1995)
- softwood cuttings root well under horticultural conditions (Dirr 1975, Vogel 1981—cited in Lapin and Nothnagle 1995)

Life History of *Celtis reticulata* Torr (synonym *C. douglasii*)

Family: Ulmaceae (Elm)

Common names: netleaf hackberry, western hackberry, paloblanco

Background

Description:

- 30-45 ft at maturity (Preston 1947, Rehder 1940—cited in Bonner 1974)
- 50 year old trees in Idaho ave. 3.9m tall and 13.6cm diameter (DeBolt and McCune 1995)
- mean age of 66 years with a range of 1–374 years (DeBolt and McCune 1995)
- diameter was often a better indicator of age than height (DeBolt and McCune 1995)
- stands are typically unimodal, with one dominant cohort (DeBolt and McCune 1995)
- populations are often small or highly localized (Daubenmire 1970, Dooley and Collins—cited in DeBolt and McCune 1995)

Range:

- widely distributed in semiarid regions of the western United States in a diversity of habitats (DeBolt and McCune 1995)
- Washington and Colorado south to west Texas and southern California (Bonner 1974)
- central Washington to northern Mexico to central Kansas, Texas, Oklahoma (Salzer et al. 1996)
- occurs from 200 to 2000m above sea level (Elias 1980—cited in Salzer et al. 1996)

Uses/Value:

- timber production, habitat or food for wildlife, shelterbelt, environmental forestry (Bonner 1974)
- first cultivated in 1890 (Preston 1947, Rehder 1940—cited in Bonner 1974)
- fruit is favored by a variety of birds and mammals (Hayward 1948, Lanner 1983—cited in DeBolt and McCune 1995)
- associated with 41 bird spp. (Asherin and Claar 1976 - cited in DeBolt and McCune 1995)
- provides cover for big game species including mule deer and bighorn sheep (Asherin and Claar 1976—cited in DeBolt and McCune 1995)
- provides shade for domestic livestock along the Snake River (Daubenmire 1970—cited in DeBolt and McCune 1995)

Growth

- prefers warmest portions of canyons, especially south-facing (Tisdale 1986—cited in DeBolt and McCune 1995)
- both riparian and upland in Idaho and locally abundant, overstory dominant (Huschle 1975, Johnson and Simon 1987—cited in DeBolt and McCune 1995)
- riparian species at high water lines; common along watercourses (Salzer et al. 1996)
- presence of *C. reticulata* is correlated with surface rock or rock outcrops, because rock fissures may hold moisture (DeBolt and McCune 1995)
- individuals at mid-slope were shrubbier in growth form (DeBolt and McCune 1995)
- typically grows tallest when located in draws on loam (DeBolt and McCune 1995)

- sensitive to late spring frost and poorly competitive with fast-growing species, in Idaho it is the last shrub to break dormancy in the spring (DeBolt and McCune 1995)
- dendrochronology maybe related to streamflow (Salzer et al. 1996)
- tolerant of harsh, water-stressed growing conditions (DeBolt and McCune 1995)

Reproduction

Sexual:

- Flowering is polygamo-monoecious (Krajicek 1965, McKnight 1965—cited in Bonner 1974)
- Flowers produced in March-April (Little 1950, Swingle 1939—cited in Bonner 1974)
- a small, fleshy drupe is produced in the fall (DeBolt and McCune 1995)
- produces good fruit crops almost yearly and fruits persist on branches into winter (Krajicek 1965, McKnight 1965, U.S.D.A. Forest Service 1948—cited in Bonner 1974)
- seeds exhibit dormancy which is overcome by stratification of 120 days at 41 degrees Fahrenheit in moist sand (Bonner 1974)
- seed dispersal occurs in fall/winter (Little 1950, Swingle 1939 - cited in Bonner 1974)
- newly established stands are apparently rare, but typically occur on riparian sites (DeBolt and McCune 1995)
- low recruitment under extreme grazing pressure (DeBolt and McCune 1995)

Asexual:

- can be propagated by cuttings (Bonner 1974)
- resprout after disturbances such as fire and herbivory (DeBolt and McCune 1995)

Life History of *Glycyrrhiza lepidota* Pursh

Family: Fabaceae (Legume)

Common names: American licorice

Background

Description:

- perennial legume (Duke 1981 - cited in Boe and Wynia 1985)

Range:

- native and widespread across much of temperate North America (Duke 1981—cited in Boe and Wynia 1985)

Uses/Value:

- utilized by livestock in the Great Plains (Weaver 1954, Johnson and Nicholas 1982—cited in Boe and Wynia 1985)

- produces highly digestible forage (Fransen and Boe 1981—cited in Boe and Wynia 1985)

- recognized for soil binding capabilities (Allen and Allen 1981, Duke 1981—cited in Boe and Wynia 1985)

Growth

- colonizes disturbed areas, draws, woods and prairie depressions in North America (Duke 1981—cited in Boe and Wynia 1985)

Reproduction

Sexual:

- seeds are susceptible to predation by bruchid beetles and poor flower production limits viable seed production in cultivated nurseries (Boe and Wynia 1985)

Asexual:

-spread rapidly by rhizomes (Allen and Allen 1981, Boe and Wynia 1985)

Life History of *Polygonum amphibium* L. (*P. coccineum*)

section: Persicaria

common names: water smartweed

Background

Description:

- semiaquatic perennial (Carter and Grace 1990, Mitchell 1976, Justice 1944)
- complex, phenotypically variable species (Hobbs 1992, Mitchell 1968—cited in Mitchell 1976)
- other *Polygonum* species include invasive weeds (Oliver 1997)

Range:

- native to the United States (Mitchell 1971—cited in Mitchell 1976)

Uses/Value:

- important as food and cover for waterfowl and fish (Justice 1944)

Growth

- thrives in water-saturated soils and standing water (Mitchell 1976)
- can tolerate long periods of inundation (Mitchell 1976, Carter and Grace 1990)
- abundant in pond and along pond shores (Justice 1944, Carter and Grace 1990)
- reduced growth in drained soil (Carter and Grace 1990)
- increased flooding results in larger shoots and less rhizomes (Carter and Grace 1990)

Reproduction

Sexual:

- perennial, low sexual reproductive effort (Carter and Grace 1990)
- achene fruit has a thick, bony pericarp which may limit germination physically and by resisting water absorption and gas exchange (Justice 1944)
- dormant seeds require low temperatures and moist storage conditions for germination (Justice 1944)
- rarely flowers or sets fruit on agricultural land (Korsmo 1930 - cited in Justice 1944)

Asexual:

- can be propagated from rhizomes (Mitchell 1976) and shoot-cuttings (Carter and Grace 1990)

Life History of *Populus trichocarpa* (*P. balsamifera* subsp. *trichocarpa*)

Family: Salicaceae Section: Tacamahaca

Common Names: black cottonwood

Background

Description:

- hardwood tree which can attain heights of 60 m and d.b.h. of 3 m (Harlow and Harrar 1950, Viereck and Little 1972—cited in DeBell 1990)
- lifespan of 100 to 200+ years (DeBell 1990)
- primarily found in alluvial habitats but also observed along lakes and wetlands, and occasionally in agricultural fields (Braatne et al. 1996)

Range:

- native to western North America, generally west of the Rocky Mountains (DeBell 1990)
- only small remnants of once abundant riparian cottonwood forests survive in most regions of the southwestern United States (Braatne et al. 1996)
- negative impacts on riparian cottonwood forests include livestock grazing, water diversion, domestic settlement, exotic plants, onstream reservoirs, channelization, agricultural clearing, gravel mining, and direct harvesting (Braatne et al. 1996)

Uses/Value:

- dominant forest species in riparian habitats of western North America and are extremely rich wildlife habitats (Finch and Ruggiero 1993—cited in Braatne et al. 1996)
- economically valuable in pulpwood plantations (DeBell 1990)

Growth

- phreatophytic (Braatne et al. 1996)
- rooting depths of mature stands is 3-5 m or greater (Braatne et al. 1996)
- cottonwood seedlings and saplings are intolerant to drought (Braatne et al. 1996)
- tolerant to inundation for extended periods of 3 to 4 weeks or more during establishment and subsequent years (Smit 1988, Mahoney and Rood 1992)

Reproduction

Sexual:

- 7 to 10 years to reproductive maturity (DeBell 1990, Dewitt and Reid 1992)
- sexual reproduction primarily dependent on high flow or flooding (Braatne et al. 1996)
- flowers produced between March and May (DeBell 1990, Dewitt and Reid 1992)
- wind or water dispersal of seeds (DeBell 1990)
- seed germination within 24 hrs on moist, bare soil (Braatne et al. 1996)
- seed viability is limited from 2 weeks to 1 month (DeBell 1990)
- seedling root growth is 4 to 12+ mm/day (Reed 1995, Mahoney and Rood 1991, 1992)
- seedlings are poor competitors in vegetated sites (Johnson et al. 1976, Fenner et al. 1984, Johnson 1994—cited in Braatne et al. 1996)

Asexual:

- easily propagated by cuttings (DeBell 1990)
- cottonwoods can regenerate asexually after crown breakage (Braatne et al. 1996) and fire disturbances (Hawkes et al. 1990)

Life History of *Salix exigua* Nuttall (subspecies or synonym *S. interior* Rowlee)

Family: Salicaceae

Common Names: sandbar willow, coyote willow, narrowleaf willow

Background

Description:

- dominant woody pioneer and stabilizer of riverbanks and sand dunes over most of North America (Ottenbreit and Staniforth 1992)
- shrubby species that forms dense clonal thickets bordering rivers, streams, ponds, marshy areas and irrigation ditches (Shaw 1991)

Uses/Value:

- provides streambank stabilization as well as food and cover for numerous wildlife species (Finch 1987, Hansen et al. 1988—cited in Shaw 1991)

Growth

- obligate phreatophyte (Busch et al. 1992—cited in Cleverly et al. 1997)
- tolerant of flooding and may occur below high water (Argus 1973—cited in Shaw 1991) and on frequently inundated and silty (mesic) sites (Krasny et al. 1988)
- prefers stable water table throughout the year (Busch and Smith 1995—cited in Cleverly et al. 1997)
- short-lived; oldest was 31 yrs old, but most were <11 (Ottenbreit and Staniforth 1992)
- growth of 0.26 cm/yr in diameter (Argus 1973, Barnes 1985—cited in Ottenbreit and Staniforth 1992) and 0.30 m/yr in height (Ottenbreit and Staniforth 1992)
- past 2 yrs old, there is a steady decline in shoot length (Price 1989)
- more successful than *Tamarix* in wet years or early successional communities (Cleverly et al. 1997)

Reproduction

Sexual:

- 93% of stems were reproductive at 9 years of age (Argus 1973, Barnes 1985—cited in Ottenbreit and Staniforth 1992)
- flowers are produced early in the spring (Densmore and Zasada 1983)
- wind mediated seed dispersal in the summertime (Krasny et al. 1988, Densmore and Zasada 1983)
- dry seeds remain viable for about 1 week (Densmore and Zasada 1983, Krasny et al. 1988)
- complete germination within 24 hours on moist seedbed at temperatures of 2 to 25°C (Densmore and Zasada 1983)
- seedlings establish on alluvial bars in rivers and on sand dunes (Scoggan 1979—cited in Ottenbreit and Staniforth 1992)

Asexual:

- sprouts well from root and shoot segments (Krasny et al. 1988)
- root suckers invade dry and frequently inundated sites (Krasny et al. 1988)
- forms dense thickets of evenly-aged clonal sprouts (Ottenbreit and Staniforth 1992)
- clonal spreading rates are greatest with a constant water table (20 cm below soil surface); there is no active spreading (stem mortality) with water table fluctuation (80 cm drop) (Ottenbreit and Staniforth 1992)
- ramet production peaks between 5 and 6 years and is minimal 9 to 11 years after establishment (Krasny et al. 1988)

Life History of *Tamarix ramosissima* Ledeb. and *T. Parviflora* (the salt cedar complex)

Family: Tamaricaceae

Common Names: salt cedar, tamarisk

Background

Description:

- loosely branched shrub or tree grows 1 to 6 m tall (Devitt et al. 1997)
- typical life span is 75 to 100 years (Horton 1977—cited in Di Tomaso 1998)
- mean width of annual growth rings were about 0.3 cm in Nevada and California (Cleverly et al. 1997)
- an invasive, exotic (Devitt et al. 1997) native to Asia (Baum 1978, Hickman 1993—cited in Manning et al. 1996)
- since its first introduction to the United States as an ornamental in the 1800s, 8 species have been introduced primarily as ornamentals and wind breaks (Di Tomaso 1998)
- 3 species are considered naturalized along streams or wet areas of (semi)arid western USA (Bensen and Darrow 1981—cited in Devitt et al. 1997)
- associated with mesquite, cottonwoods, and willow but eventually replaces these natural riparian species (Frasier and Johnsen 1991—cited in Di Tomaso 1998)

Range:

- widespread, most common in Arizona and California (Di Tomaso 1998)
- in the 1920s, it covered about 4,000 ha of riparian habitat in southwestern United States (Neill 1985 - cited in Di Tomaso 1998), in 1987 it covered at least 600,000 ha (Brotherson and Field 1987—cited in Di Tomaso 1998)
- spreading north into Montana and Canada (DeLoach 1989, Swenson et al. 1982—cited in Di Tomaso 1998) and south to northeastern Mexico (DeLoach 1989—cited in Di Tomaso 1998)
- naturalized, dominant species along the Colorado River drainage (Baum 1967—cited in Devitt et al. 1997) which has replaced up to 90% of lower Colorado River riparian communities that were typically dominated by cottonwoods and willows (Crins 1989—cited in Sala et al. 1996)

Uses/Value:

- until the twentieth century, salt cedar was considered to have a positive effect on riparian ecosystems; stabilizing effect on the lake edge soils and its ability of desalinate the lower solid profiles were considered desirable features (Goldsmith and Smart 1982—cited in Di Tomaso 1998)
- extensive root system is more stable and resistant to erosion than most native riparian trees and shrubs (Di Tomaso 1998)
- attractive ornamental with showy white or pink flowers (Di Tomaso 1998)
- beekeepers use salt cedar for honey production (Everitt 1980—cited in Di Tomaso 1998)

Negative features:

- rarely provides food and shelter necessary for the survival of wildlife (Shrader 1977—cited in Di Tomaso 1998)
- monoculture invasion resulted in the loss of many vertebrate species, birds (Anderson et al. 1977, Cohan et al. 1978—cited in Gladwin and Roelle 1998) and the elimination of native riparian plants (Busch and Smith 1995—cited in Cleverly et al. 1997) such as

- cottonwoods and willows (Ohmart and Anderson 1982—cited in Gladwin and Roelle 1998)
- salt cedar stands consistently have lower total bird density and species diversity than communities dominated by cottonwood, willow, and mesquite (Anderson et al. 1977, Cohan et al. 1978, Engel-Wilson and Ohmart 1978, Hunter et al. 1985, 1988, Kerpez and Smith 1987—cited in Di Tomaso 1998)
- with the exception of woodrats and desert cottontail, no native mammals feed on mature salt cedar (Di Tomaso 1998)
- they consume large amounts of water (VanHylekama 1974, Gay and Fritschen 1979, Davenport et al. 1982—cited in Sala et al. 1996, Decker et al. 1962—cited in Devitt et al. 1997) resulting in the desiccation of floodplains, lower water tables, springs, pools, and even perennial streams (Blackburn et al. 1982—cited in Cleverly et al. 1997, Robinson 1965 and Rowlands 1990—cited in Manning et al. 1996, Johnson 1987—cited in Di Tomaso 1998)

Growth

Preferences:

- occupies sites with silt loams and silt clay loams high in organic matter, intermediate moisture, high water tables, and little erosion (Brotherson and Winkel 1986—cited in Di Tomaso 1998)
- grows at elevations no greater than 2100 m and prefers saline soils (Di Tomaso 1998)
- halophytic (Busch and Smith 1993)
- salt cedar rapidly infests riparian areas exposed to heavy grazing; seasonal grazing provides a competitive advantage to native willows and cottonwoods (Hughes 1993—cited in Di Tomaso 1998)

Root characteristics:

- during the first 4 weeks of seedling development, root growth is slow and seedlings will die if the soil is dry for more than one day (Kerpez and Smith 1987—cited in Di Tomaso 1998)
- seedling root growth is slower than other riparian species (Everitt 1980—cited in Di Tomaso 1998)
- root grows steadily downward with little branching from the lateral roots until it reaches the water table (Horton 1977—cited in Di Tomaso 1998)
- tap roots typically reach depths of 5 meters (Brotherson and Field 1987, Brotherson and Winkel 1986 - cited in Di Tomaso 1998) but may extend as deep as 50 meters (Baum 1978—cited in Di Tomaso 1998)

Water Requirements:

- facultative phreatophyte (Busch et al. 1992, Cleverly et al. 1997)
- may draw moisture from the saturated zones below the water table and can extract soil moisture from less saturated soils in areas with deeper water tables (Everitt 1980—cited in Di Tomaso 1998)
- once established, salt cedar can survive almost indefinitely in the absence of saturation of the soil (Brotherson and Field 1987—cited in Di Tomaso 1998)
- dense stands typically occur where water tables are 1.5 to 6 m below the surface (Horton and Campbell 1974, Kerpez and Smith 1987, Sala et al. 1996—cited in Di Tomaso 1998)

- mature salt cedar is tolerant to mechanical injury caused by cutting, grazing, and burning and environmental stresses including heat, cold, drought, water inundation, and high concentrations of dissolved solids (Brotherson and Field 1987, Everitt 1980, Frasier and Johnsen 1991—cited in Di Tomaso 1998)
- much higher transpiration per unit sapwood area than some other phreatophytes (Sala et al. 1996—cited in Cleverly et al. 1997)
- stomata capable of long-term regulation (Devitt et al. 1997)
- low xylem pressure required to cause cavitation (Devitt et al. 1997)
- rates of evapotranspiration among the highest of phreatophytes in southwestern North America including native riparian trees (Van Hylckama 1974, Busch and Smith 1995, Neill 1985—cited in Di Tomaso 1998)

Drought tolerance:

- tolerant of watercourse desiccation and long-term drought (Blackburn et al. 1982—cited in Cleverly et al. 1997, Devitt et al. 1997)
- survives severe drought by transpiring earlier in the day and dropping leaves to reduce evapotranspiration (Horton and Campbell 1974 - cited in Di Tomaso 1998)
- stands can transpire large amounts of water (Sala et al. 1996)

Flooding tolerance:

- mature plants are able to survive complete submergence in water for as long as 70 days (Brotherson and Field 1987, Kerpez and Smith 1987, Warren and Turner 1975—cited in Di Tomaso 1998)
- adventitious roots develop easily from submerged or buried salt cedar stems (Everitt 1980, Kerpez and Smith 1987—cited in Di Tomaso 1998)
- moderately flood tolerant seedlings (Horton et al. 1960—cited in Gladwin and Roelle 1998)
- first year salt cedar does not survive well after fall flooding, but plants survive prolonged spring flooding in 2nd year (Gladwin and Roelle 1998)
- seedlings can survive submerged for a few weeks but are easily uprooted even by a weak current for several months after germination (Kerpez and Smith 1987—cited in Di Tomaso 1998)

Salt tolerance:

- tolerates soluble salt concentrations in soils ranging from 650 to 36,000 ppm and averaging 6,000 and 8,000 ppm (Brotherson and Winkel 1986, Carman and Brotherson 1982, Gatewood et al. 1950, Jackson et al. 1990—cited in Di Tomaso 1998)
- secretes excess salts through leaf glands (Decker 1961, Berry 1970, Kleinkopf and Wallace 1974—cited in Sala et al. 1996)
- invades by desiccating watercourses and salinizing soil surface (Vitousek 1990, Busch and Smith 1995—cited in Devitt et al. 1997)
- tamarisk is tolerant of high levels of boron (U.S. Salinity Laboratory Staff 1954—cited in Busch and Smith 1993)

Reproduction

Sexual:

- can reach reproductive maturity in first year (Ohmart and Anderson 1982—cited in Gladwin and Roelle 1998, Neill 1985—cited in Di Tomaso 1998)
- can flower throughout the entire growing season from April to October at lower elevations (Everitt 1980—cited in Di Tomaso 1998)
- seeds are produced from mid-July to October in Colorado (Gladwin and Roelle 1998)

- a single plant can produce half a million seeds per year (Di Tomaso 1998)
- seeds are small and light (0.1 mg) (Sisneros 1991—cited in Di Tomaso 1998) and tufted for wind and water dispersal (Brotherson and Field 1987—cited in Di Tomaso 1998)
- seed is released later in the growing season (Warren and Turner 1975—cited in Gladwin and Roelle 1998) and over a longer period than cottonwood (Reynolds and Alexander 1974, Schreiner 1974—cited in Gladwin and Roelle 1998)
- seeds produced late in the growing season can retain viability until the next spring (Merkel and Hopkins 1957, Horton et al. 1960—cited in Gladwin and Roelle 1998)
- wetted seeds germinate within 24 hrs (Kerpez and Smith 1987—cited in Di Tomaso 1998)
- germinates and survives in highly saline soils (Brotherson and Winkle 1986, Shafroth et al. 1995—cited in Sala et al. 1996)
- seeds have high initial viability and will remain viable under normal conditions for about 5 weeks (Everitt 1980—cited in Di Tomaso 1998)
- seeds will germinate rapidly, but new seedlings require wet soil for several weeks (Horton 1977—cited in Di Tomaso 1998)
- seedling establishment requires at least 4 to 6 weeks without subsequent inundation (Kerpez and Smith 1987, Shrader 1977—cited in Di Tomaso 1998)
- seedlings are tolerant of drought and inundation (Sala et al. 1996)
- seedlings establish along riverbanks where there is high soil moisture and shallow depth to water table and require floods to establish in other areas (Devitt et al. 1997)
- under ideal conditions, seedlings can grow 3 to 4 meters in a single season (Friederici 1995, Sisneros 1991—cited in Di Tomaso 1998)

Asexual:

- resprouting following fire (Busch 1995) has led to rapid colonization of water courses throughout southwestern North America (Crins 1989—cited in Busch and Smith 1993)
- Tamarix leaf litter is highly flammable (Ohmart and Anderson 1982—cited in Busch and Smith 1993) and fuel buildup by salt cedar promotes a fire every 10 to 20 years in North American desert settings (Lovich et al. 1994—cited in Di Tomaso 1998)

Fire adaptation:

- high water use and hydraulic efficiency in burned tamarisk facilitates recovery following fire in low-elevation riparian habitats (Busch and Smith 1993—cited in Busch 1995)
- water or salinity-stress tolerant shrubs are likely to maintain or expand their dominance with repeated burning of low-elevation riparian communities (Busch 1995)

Control

- mechanical and herbicide removal successful on small areas (Sudbrock 1993—cited in Gladwin and Roelle 1998)
- pocket gopher (*Thomomys bottae*) can kill and damage some salt cedar but no other control methods are known (Manning et al. 1996)

Life History of *Xanthium strumarium*

Family: Compositae Section: Xanthium=Euxanthium DC

Common names: cocklebur, clotbur, ditchbur, sheepbur, noogoora bur

Background

Description:

- a herbaceous annual weed that grows up to 1-2 m tall in natural settings (Solomon 1989)
- common along shorelines and cultivated areas (Weaver and Lechowicz 1983)
- nearly world-wide temperate distribution (Solomon 1989, Weaver and Lechowicz 1983)
- centers of distribution:
 - X. strumarium* subsp. *strumarium* : Mediterranean-Eurasian
 - X. strumarium* subsp. *cavanillesii* : America
 - X. strumarium* subsp. *strumarium* : 1 Mediterranean-Eurasian and 6 in America
- reintroductions between the Old and New World have probably occurred (Weaver and Lechowicz 1983)
- not common in mountainous regions (Love and Dansereau 1959—cited in Weaver and Lechowicz 1983)
- latitude distribution 53°N to 33°S (Holm et al. 1977—cited in Weaver and Lechowicz 1983)
- has specialized predators (Hare 1980—cited in Solomon 1989)

Uses/Value:

- major weed of soybeans and cotton in the United States (Cooley and Smith 1973, Barrentine 1974—cited in Weaver and Lechowicz 1983)
- minor weed of 11 crops in 28 countries, and considered a nuisance to livestock (Holm et al. 1977—cited in Weaver and Lechowicz 1983)
- young seedlings are poisonous to livestock (Kingsbury 1964, Holm et al. 1977—cited in Weaver and Lechowicz 1983)
- adult plants not eaten because of the burs but have favourable nutritional value (Marten and Anderson 1975, Holm et al. 1977—cited in Weaver and Lechowicz 1983)

Growth

- prefers open communities, will disappear if shaded or crowded (Love and Dansereau 1959, Kaul 1971—cited in Weaver and Lechowicz 1983)
- prefers compact sandy soil, slightly moist below surface with some organic matter (Love and Dansereau 1959, Kaul 1965c—cited in Weaver and Lechowicz 1983)
- occupies unstable habitats and continually shifts to newly disturbed areas (Weaver and Lechowicz 1983)
- tap root (Weaver and Lechowicz 1983) follows the depth of the water table (Kaul 1968—cited in Weaver and Lechowicz 1983)
- prefers water table of 5–90 cm below soil surface (Kaul 1961, 1968—cited in Weaver and Lechowicz 1983)
- roots can spread laterally 2.1m and 1.2 m deep (Davis et al. 1965—cited in Weaver and Lechowicz 1983)
- tolerates frequent flooding at all stages of growth (Kaul 1961, 1965c, 1968—cited in Weaver and Lechowicz 1983)

- tolerates saline conditions (Kaul 1961, 1965c - cited in Weaver and Lechowicz 1983)
- C3 photosynthetic pathway (Sharkey and Raschke 1981—cited in Weaver and Lechowicz 1983)
- can assimilate both nitrate and ammonia nitrogen (Wallace and Pate 1967—cited in Weaver and Lechowicz 1983)

Reproduction

Sexual:

- monoecious and wind-pollinated (Solomon 1989)
- determinate flowering, classic short-day plant (Solomon 1989, Weaver and Lechowicz 1983)
- flowering begins in early to mid-August (Weaver and Lechowicz 1983)
- will not flower or fruit in full shade (Kaul 1971—cited in Weaver and Lechowicz 1983)
- male inflorescence is a cluster of 100-150 flowers, female has 2 flowers with a spiny bur (Solomon 1989)
- self-compatible and predominately self-pollinated, interbreed readily to produce hybrids (Love and Dansereau 1959—cited in Weaver and Lechowicz 1983)
- highly inbred (Weaver and Lechowicz 1983, Hocking and Liddle 1986—cited in Blais and Lechowicz 1989)
- a single plant produces 500-2300 burs (Hicks 1971, Kaul 1965a—cited in Weaver and Lechowicz 1983) which are dispersed during autumn or winter, and occasionally in the spring (Weaver and Lechowicz 1983)
- burs are buoyant and will remain floating up to 30 days (Kaul 1961, 1965a—cited in Weaver and Lechowicz 1983)
- only one seed germinates per bur (Salisbury 1969—cited in Solomon 1989)
- larger 'lower', normally germinates in the spring, 'upper' germinates later in the season or the following year, some populations produce twin seedlings (Hicks 1971—cited in Weaver and Lechowicz 1983)
- seeds overwinter on or below the soil surface (Weaver and Lechowicz 1983)
- high moisture requirement for seed germination (Kaul 1968—cited in Weaver and Lechowicz 1983)
- no light is required for germination, seedlings seldom germinate on the soil surface or buried more than 15 cm below the soil surface (Kaul 1965b, Stoller and Wax 1973, 1974—cited in Weaver and Lechowicz 1983)
- seedling emergence takes an average of 10 days (Weaver and Lechowicz 1983)
- will establish on beaches with sandy soil (Love and Dansereau 1959—cited in Solomon 1989), in agricultural fields (Weaver and Lechowicz 1983—cited in Solomon 1989), and along shorelines of rivers (Love and Dansereau 1959; Hardtl 1963—cited in Blais and Lechowicz 1989)

Asexual:

- spreads by seeds only, but young plants regenerate readily from lower nodes if trampled, clipped, or otherwise injured (Weaver and Lechowicz 1983)

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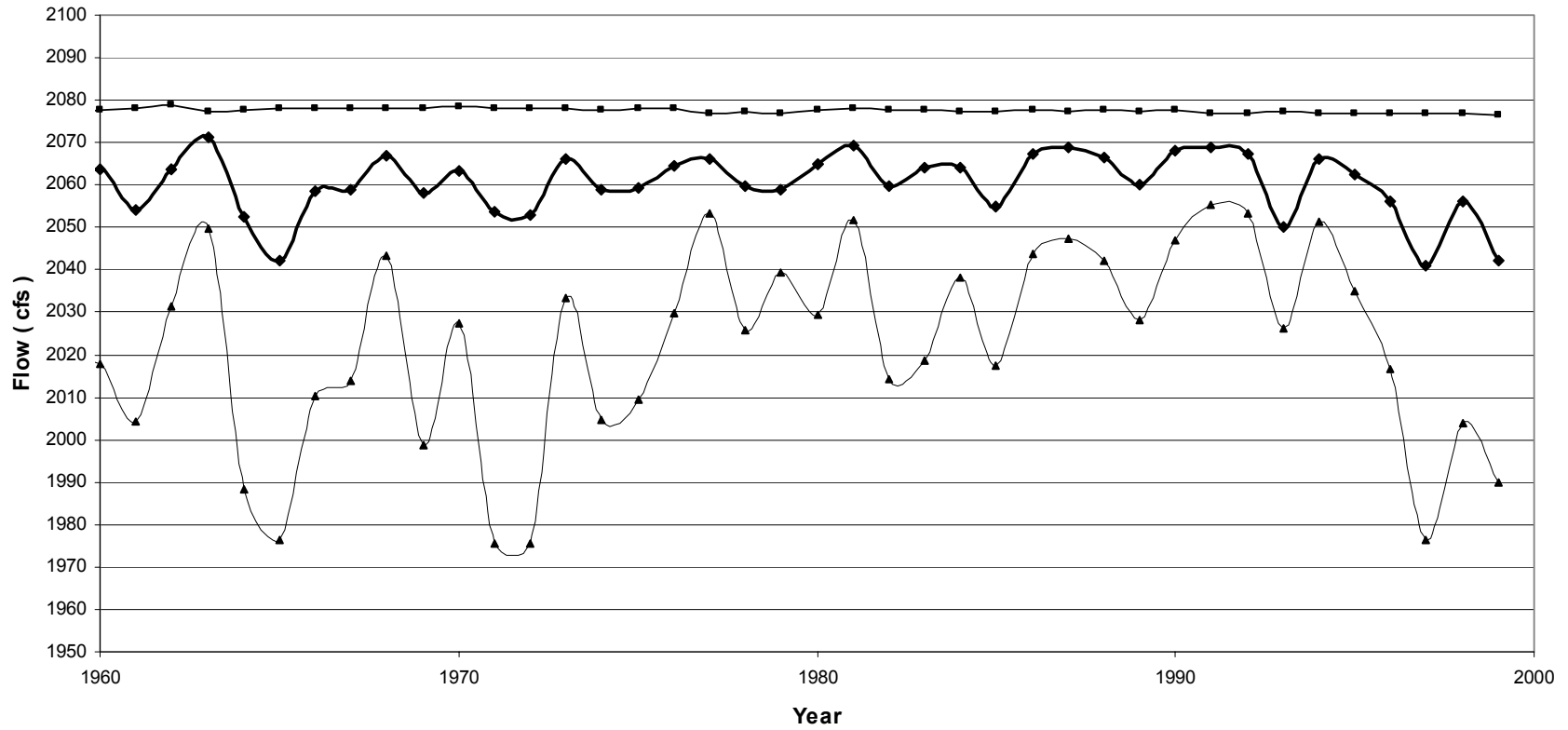
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Appendix 3.3. Historic Reservoir Water Level Fluctuations

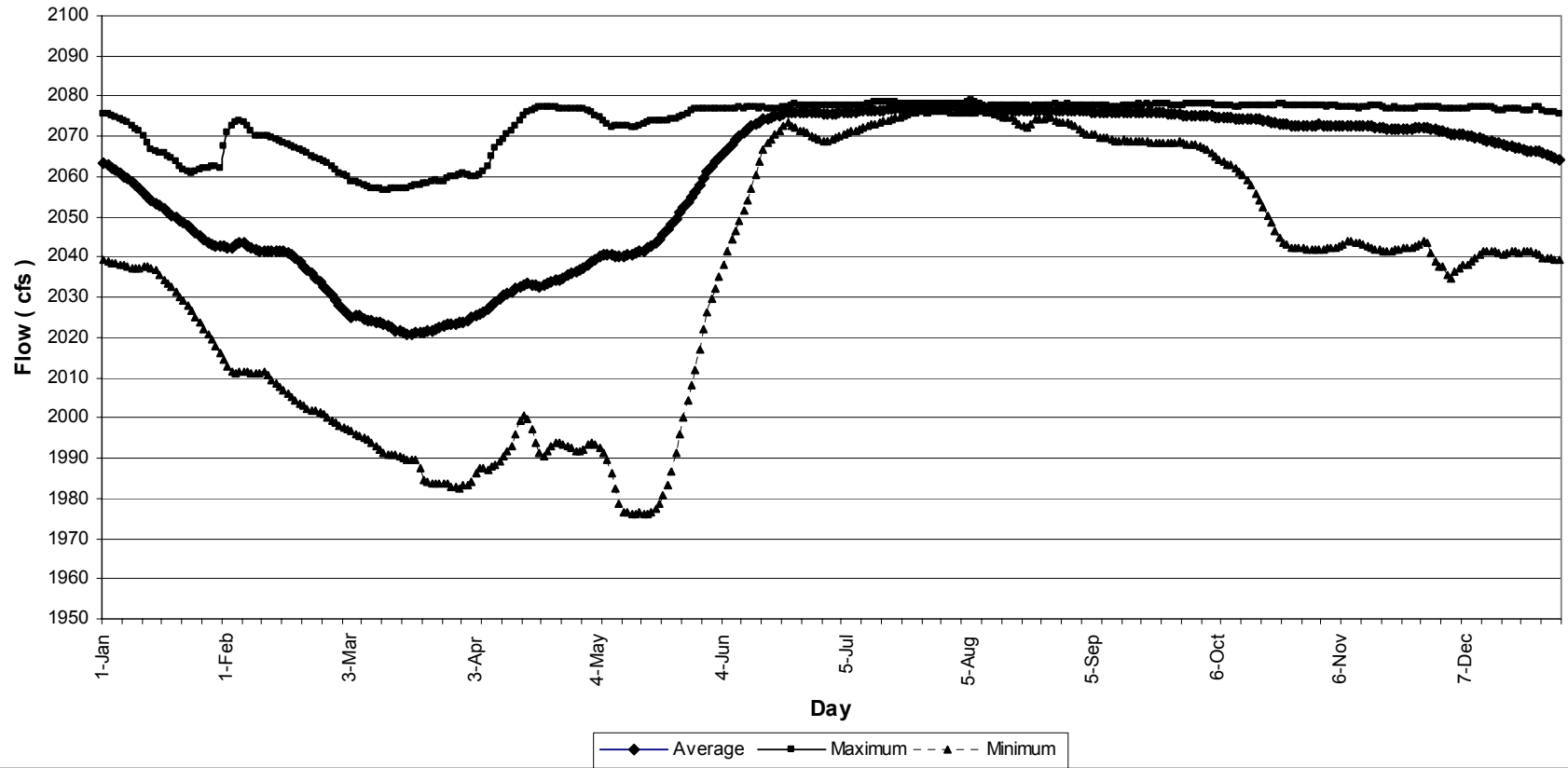
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Historic Water Surface Elevation at Brownlee Reservoir

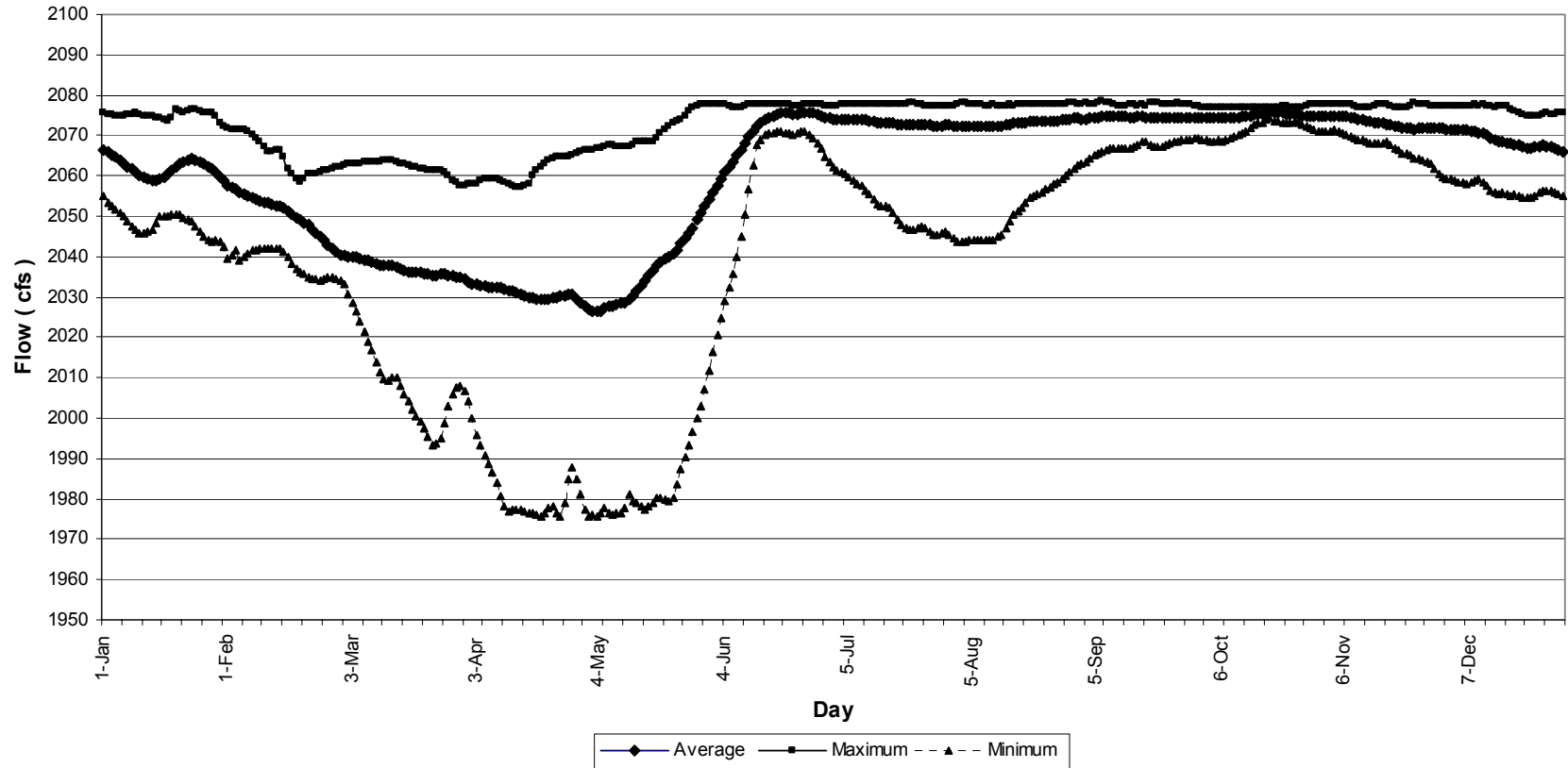


◆ Average Annual ■ Maximum Daily ▲ Minimum Daily

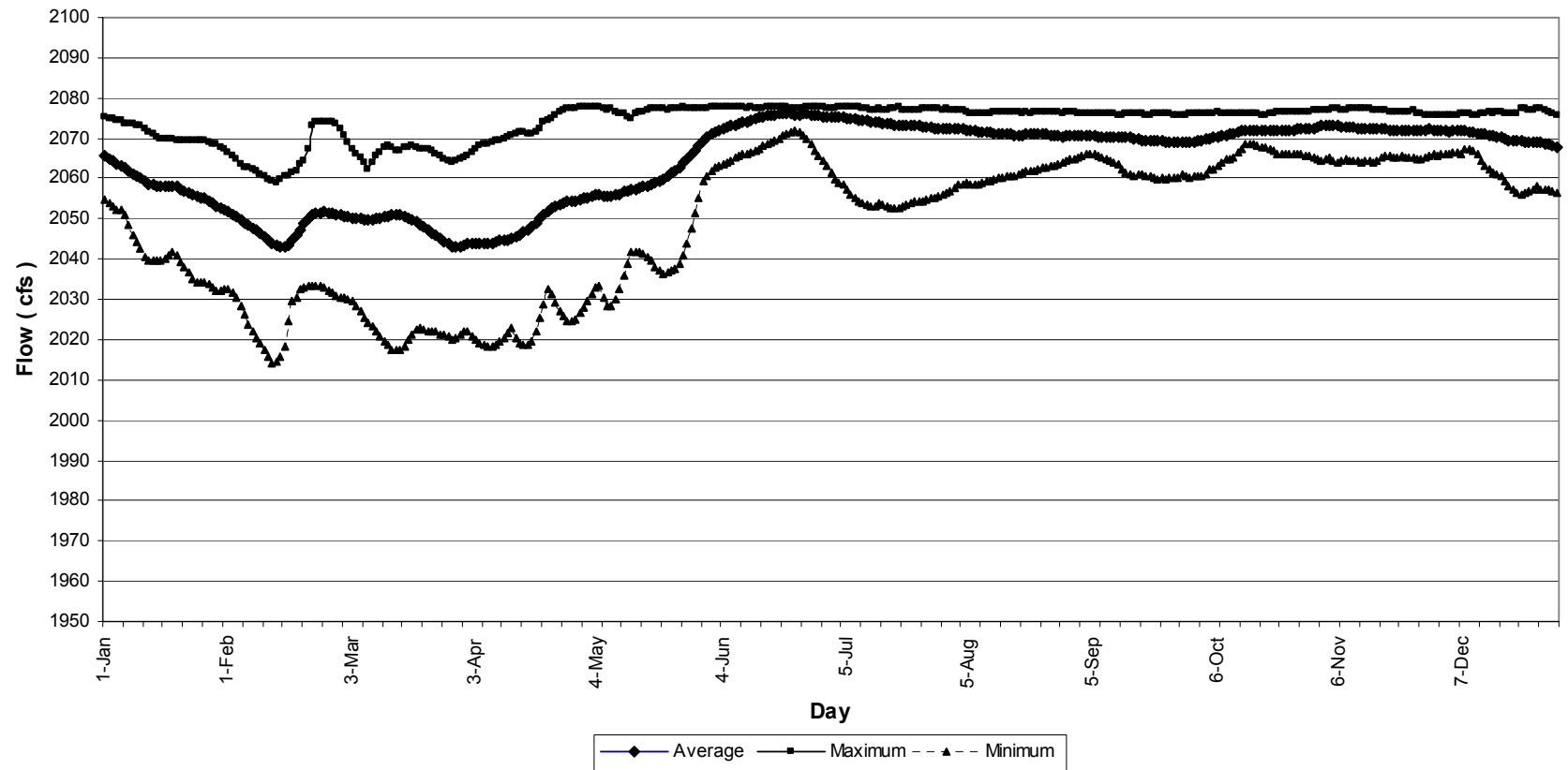
Brownlee Reservoir Historic Water Surface Elevation - From 1960 to 1969



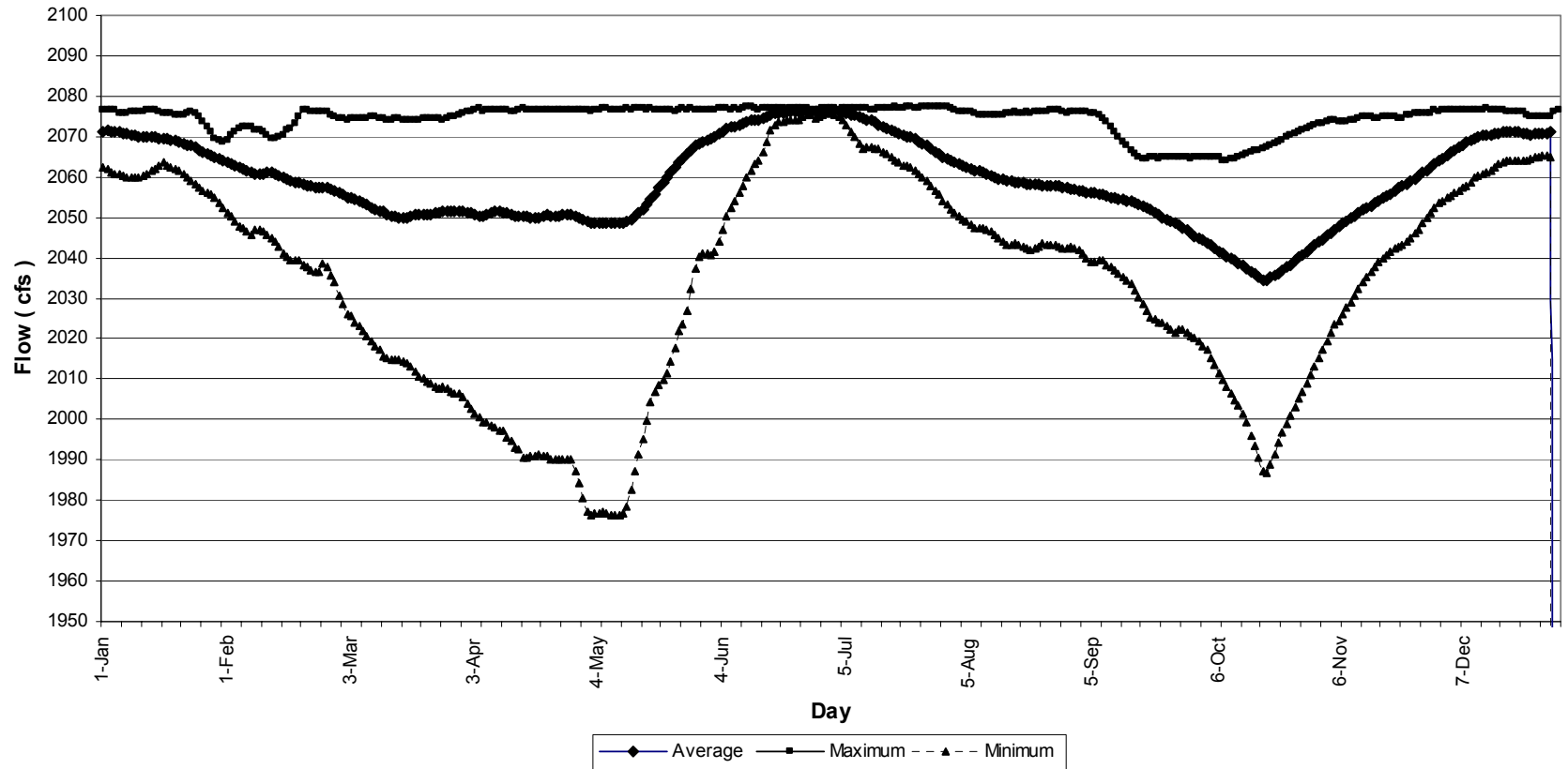
Brownlee Reservoir Historic Water Surface Elevation - From 1970 to 1979



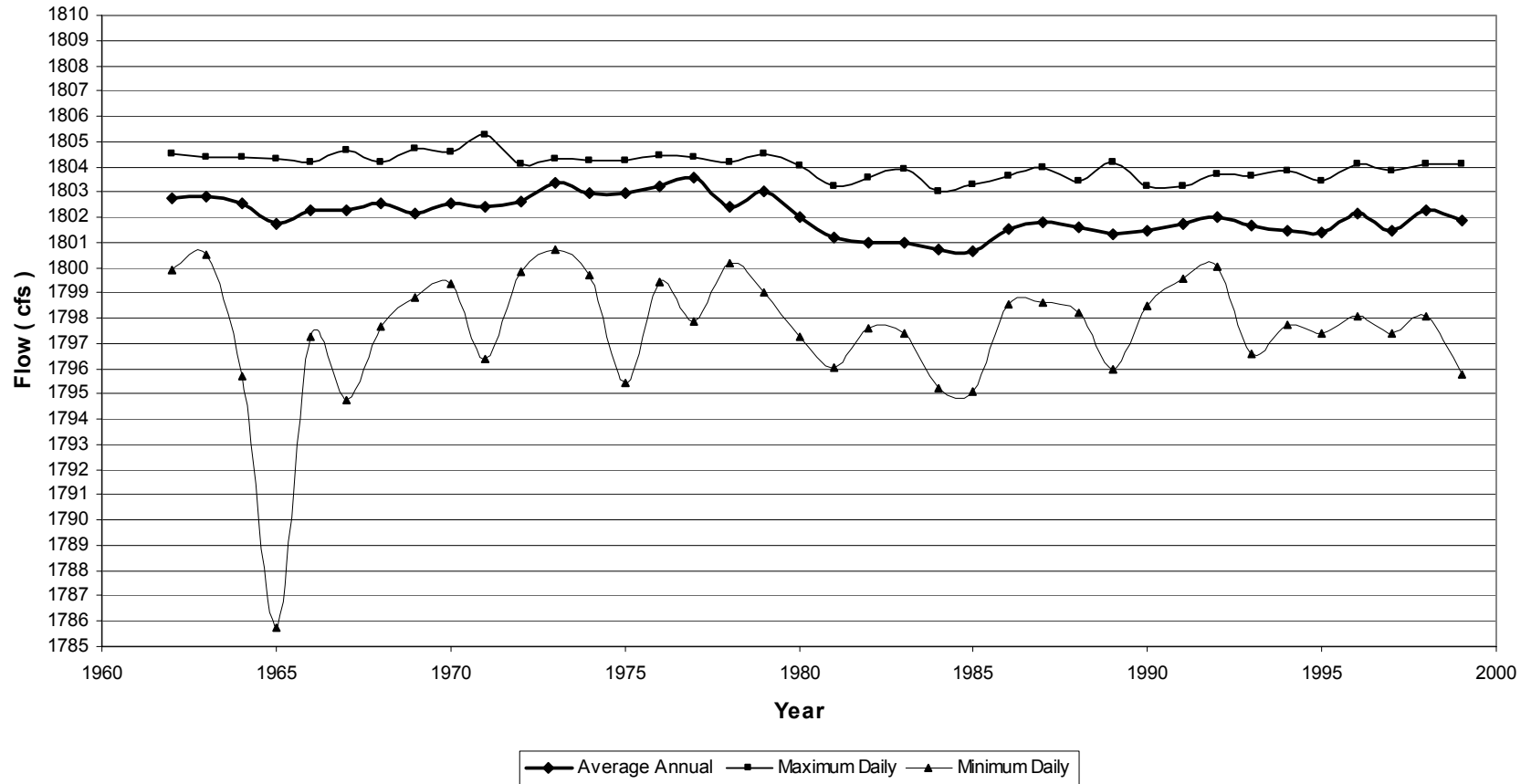
Brownlee Reservoir Historic Water Surface Elevation - From 1980 to 1989



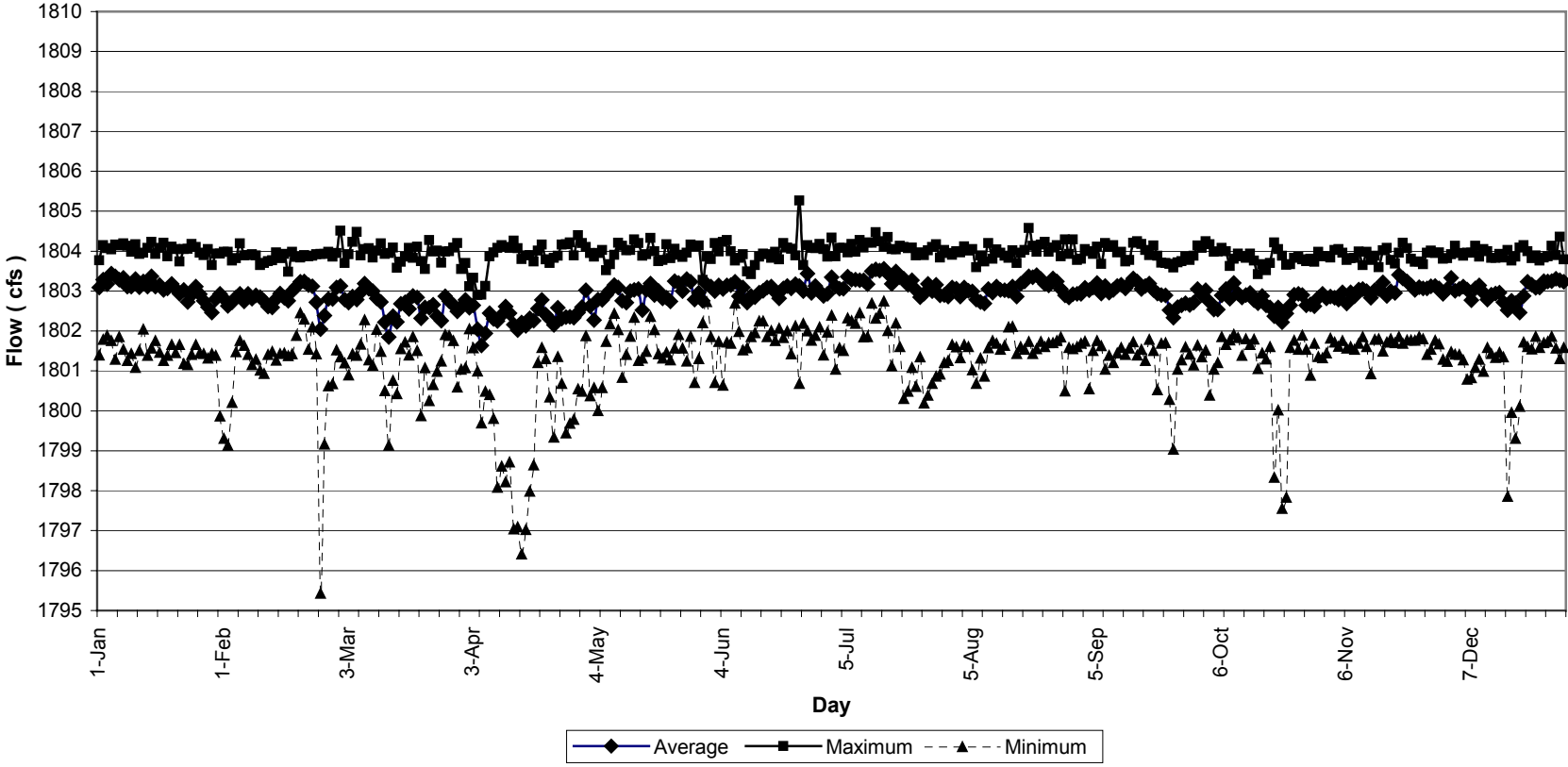
Brownlee Reservoir Historic Water Surface Elevation - From 1990 to 1999



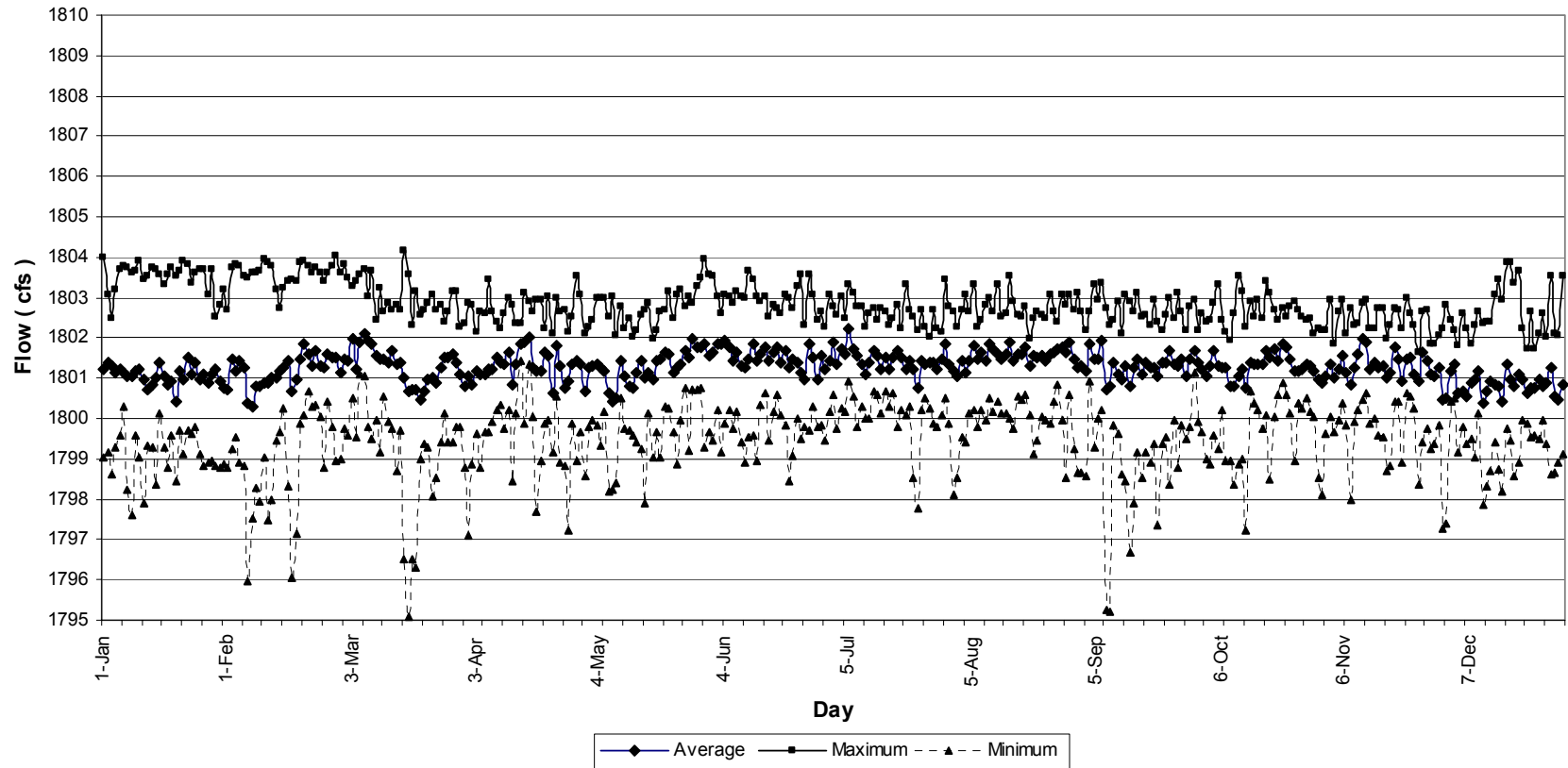
Historic Water Surface Elevation at Oxbow Reservoir



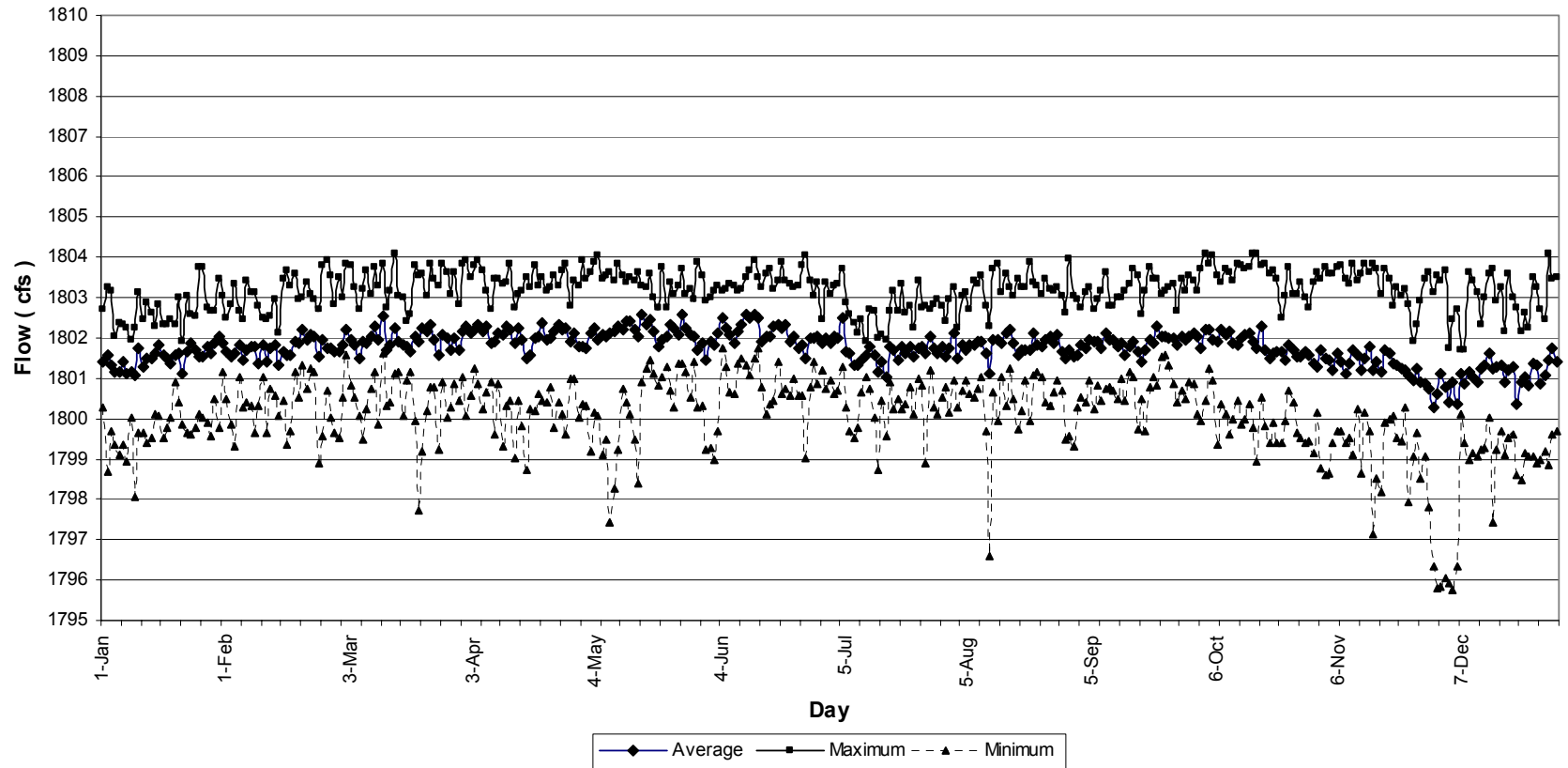
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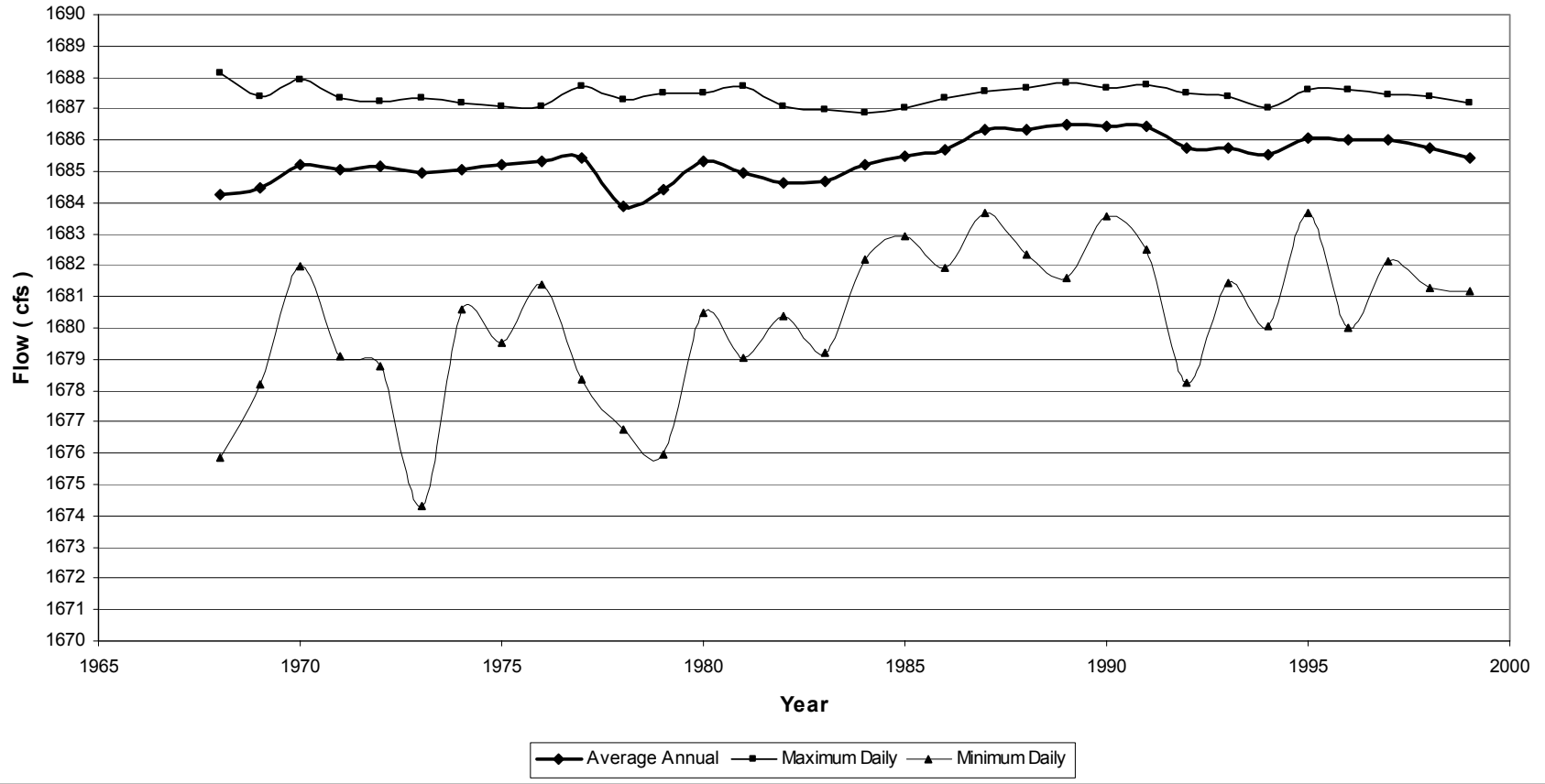
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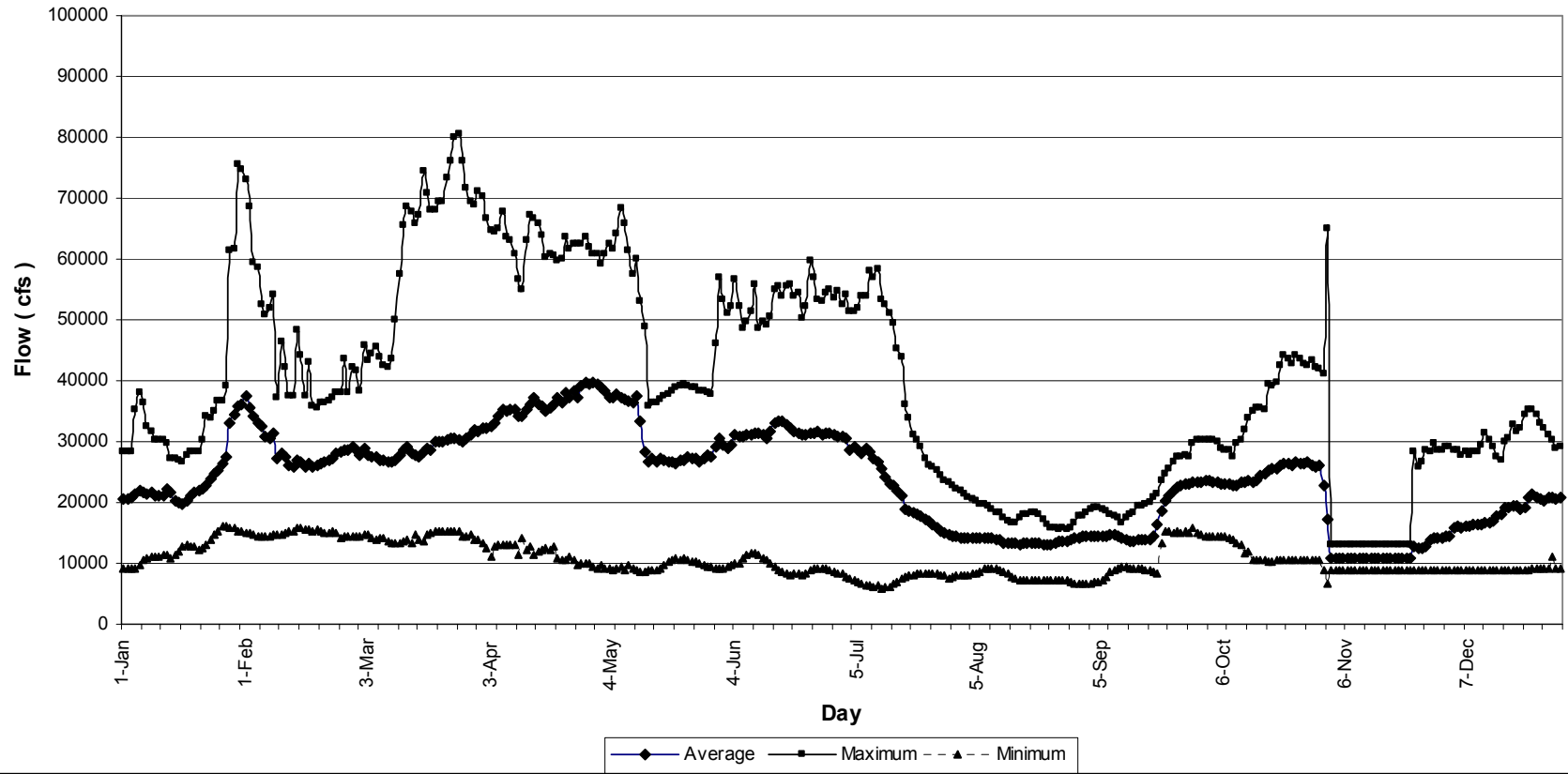
Oxbow Reservoir Historic Water Surface Elevation - From 1990 to 1999



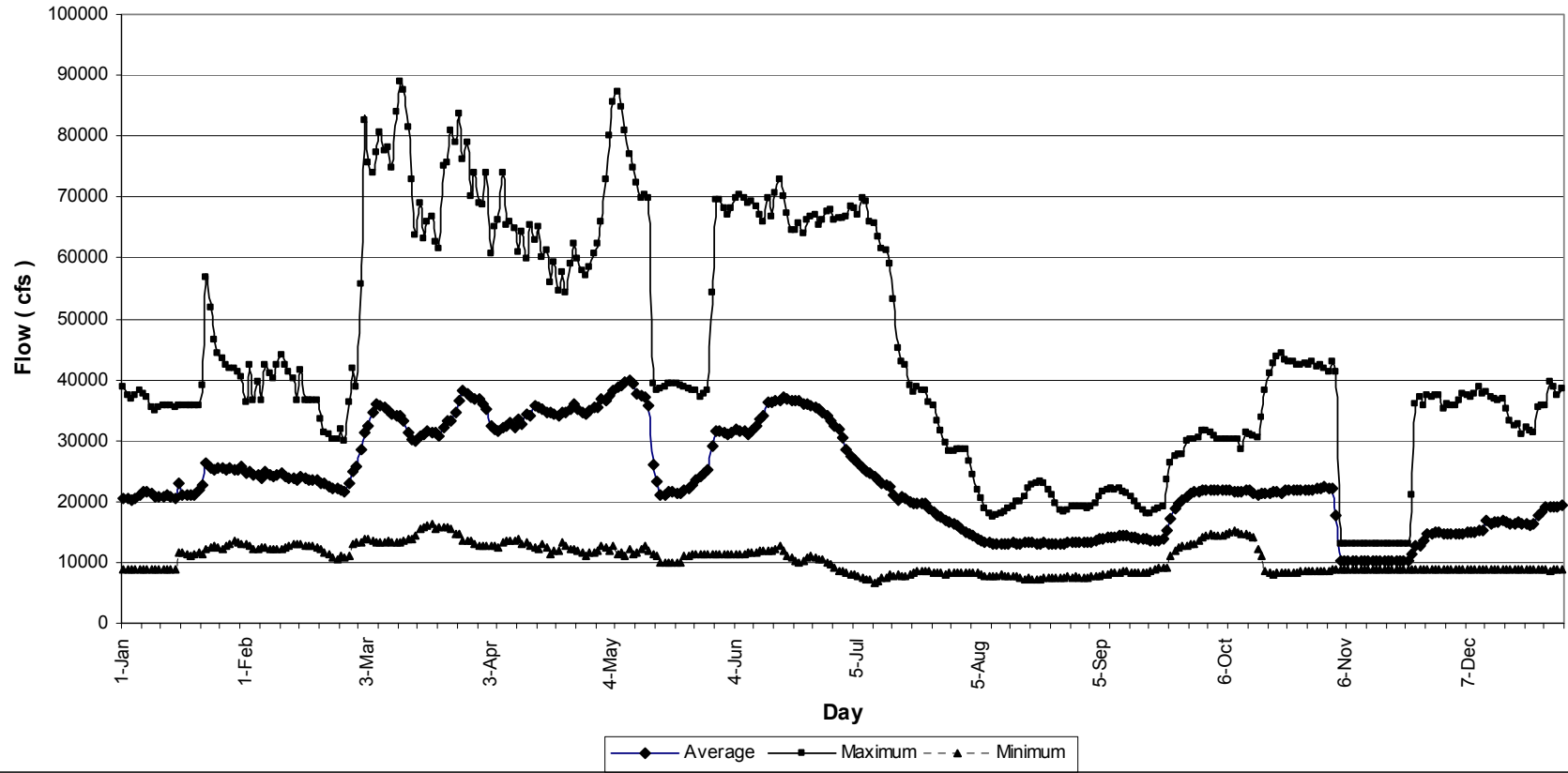
Historic Water Surface Elevation at Hells Canyon Reservoir



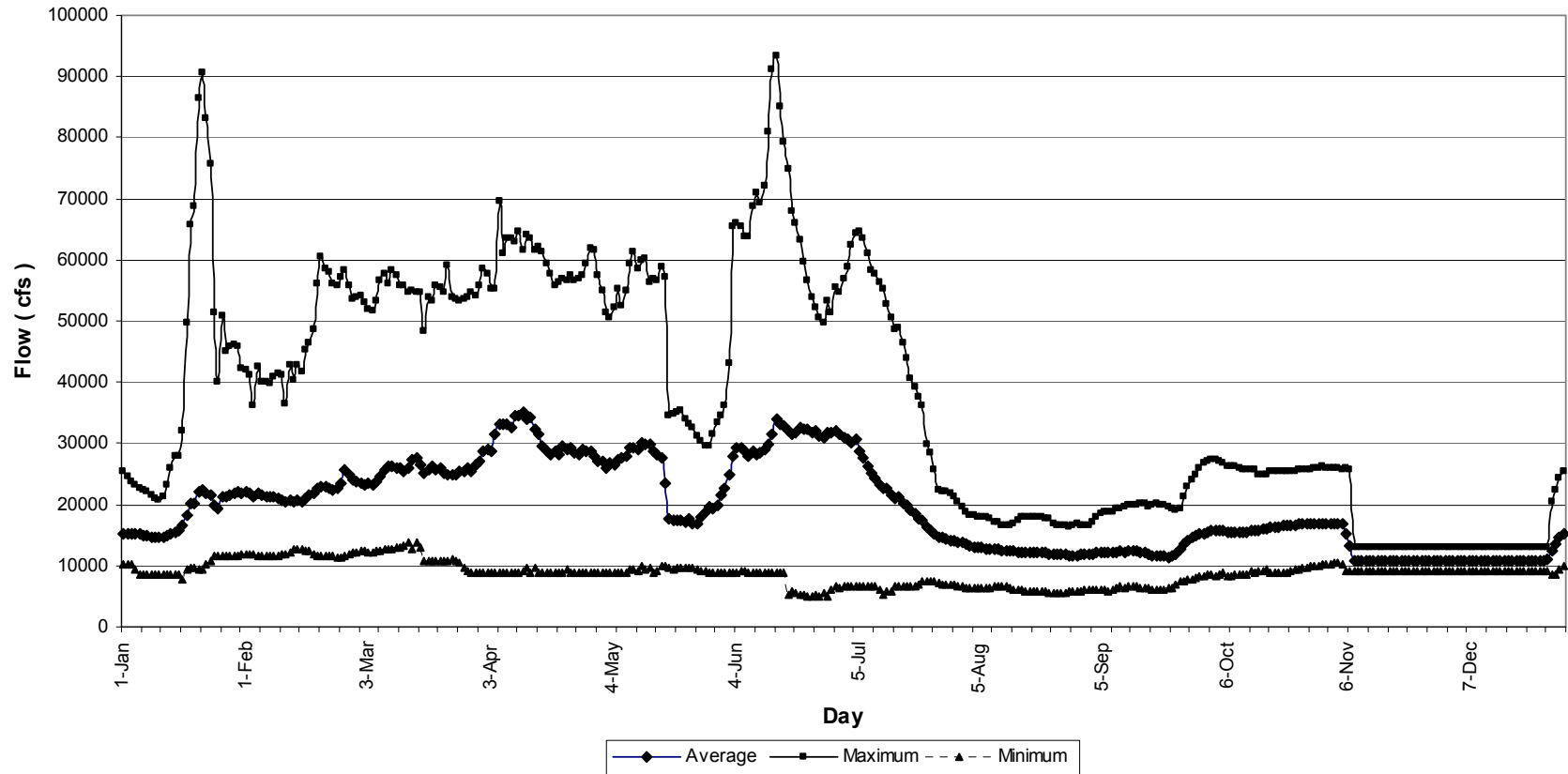
Flow at Hells Canyon Dam - Proposed (1970 to 1979)



Flow at Hells Canyon Dam - Proposed (1980 to 1989)



Flow at Hells Canyon Dam - Proposed (1990 to 1999)

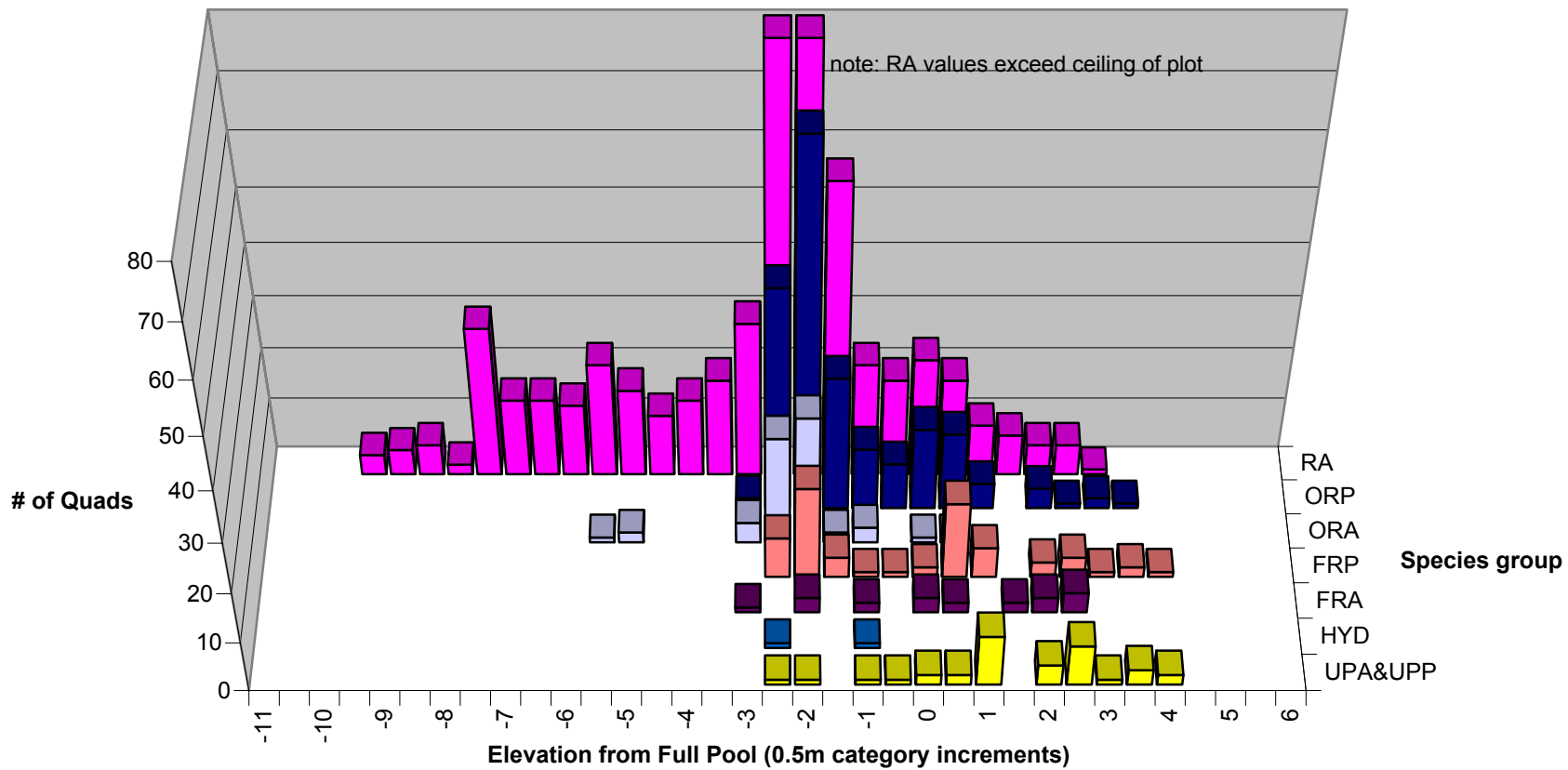


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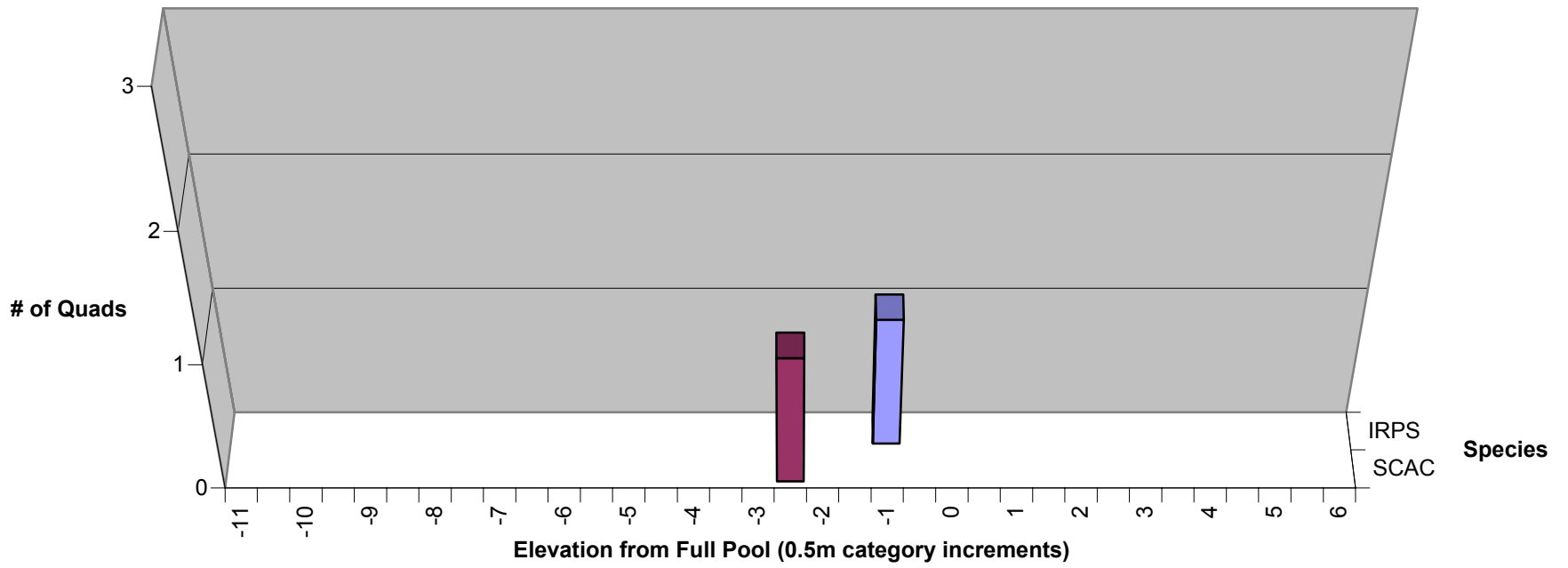
Appendix 3.4. Elevation Distributions of Vegetation (Hells Canyon Complex Reservoirs).

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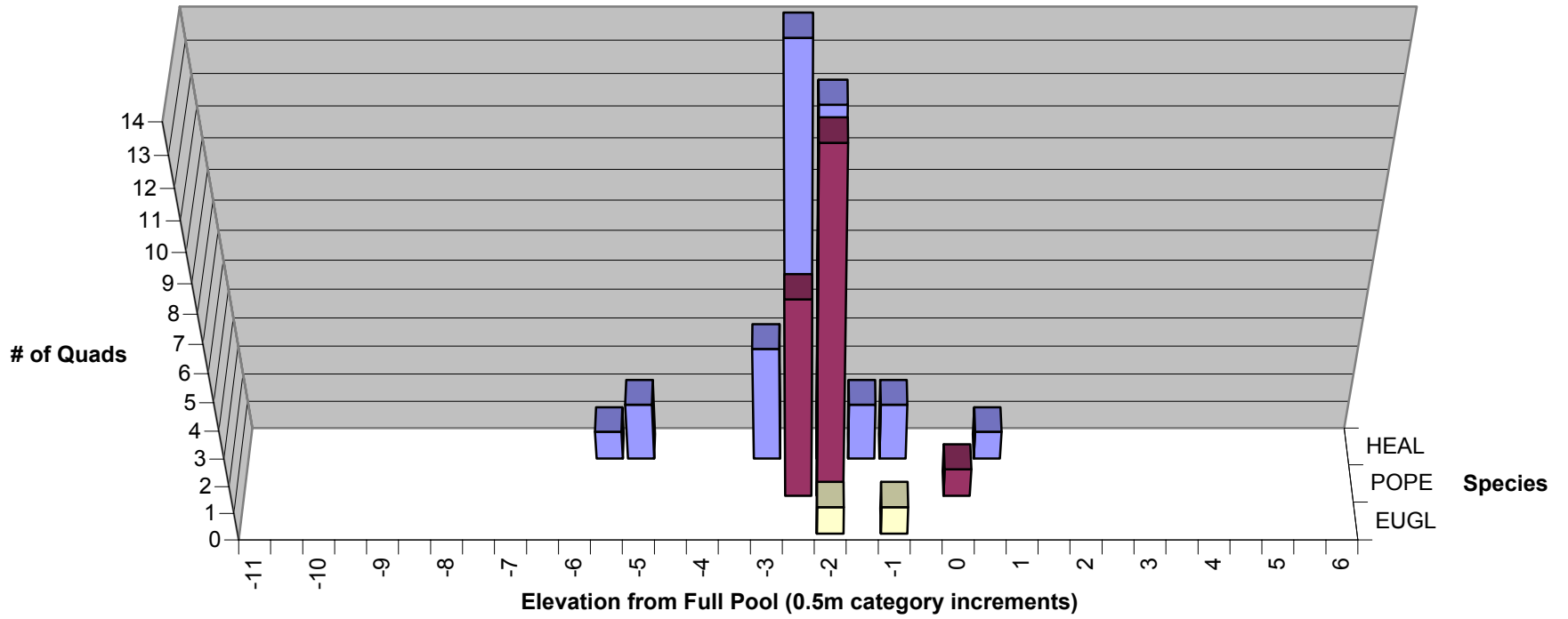
Brownlee Reservoir Headwater - Elevational Occurrence of Groups



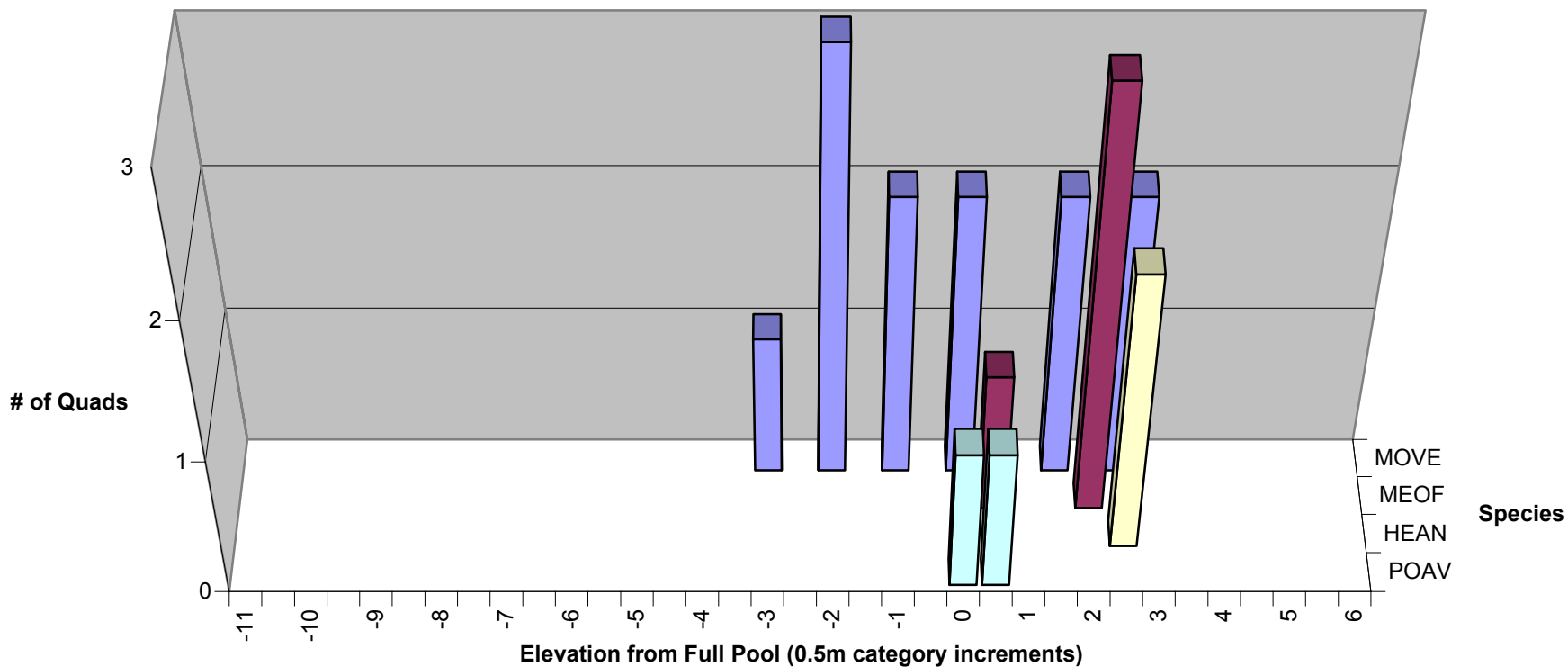
Brownlee Reservoir Headwater - Elevational Occurrence of HYD species



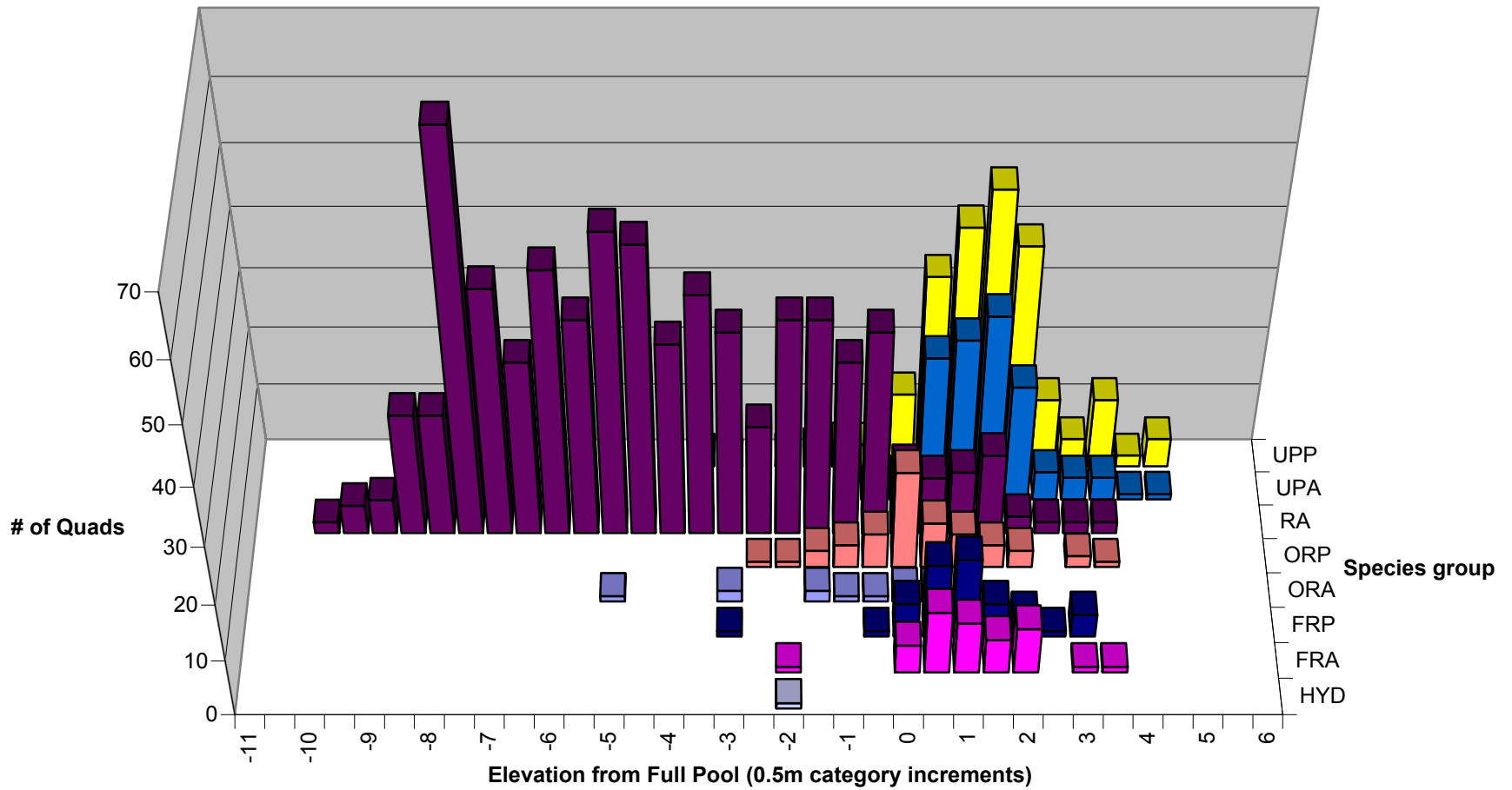
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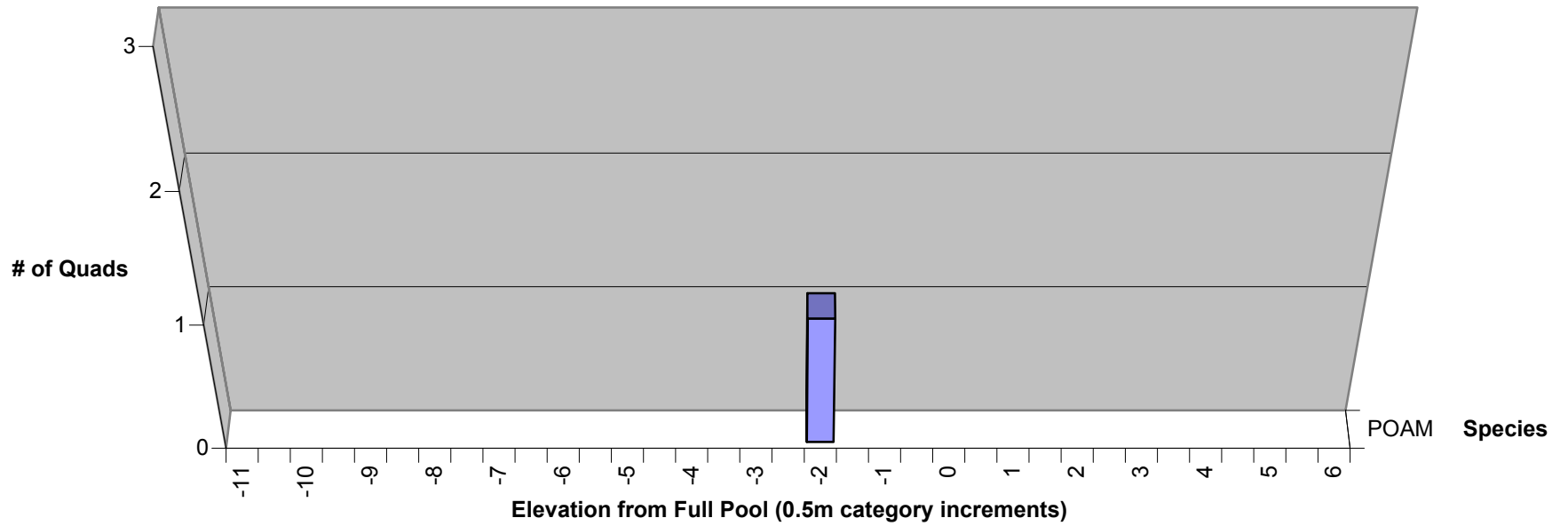
Brownlee Reservoir Headwater - Elevational Occurrence of FRA species



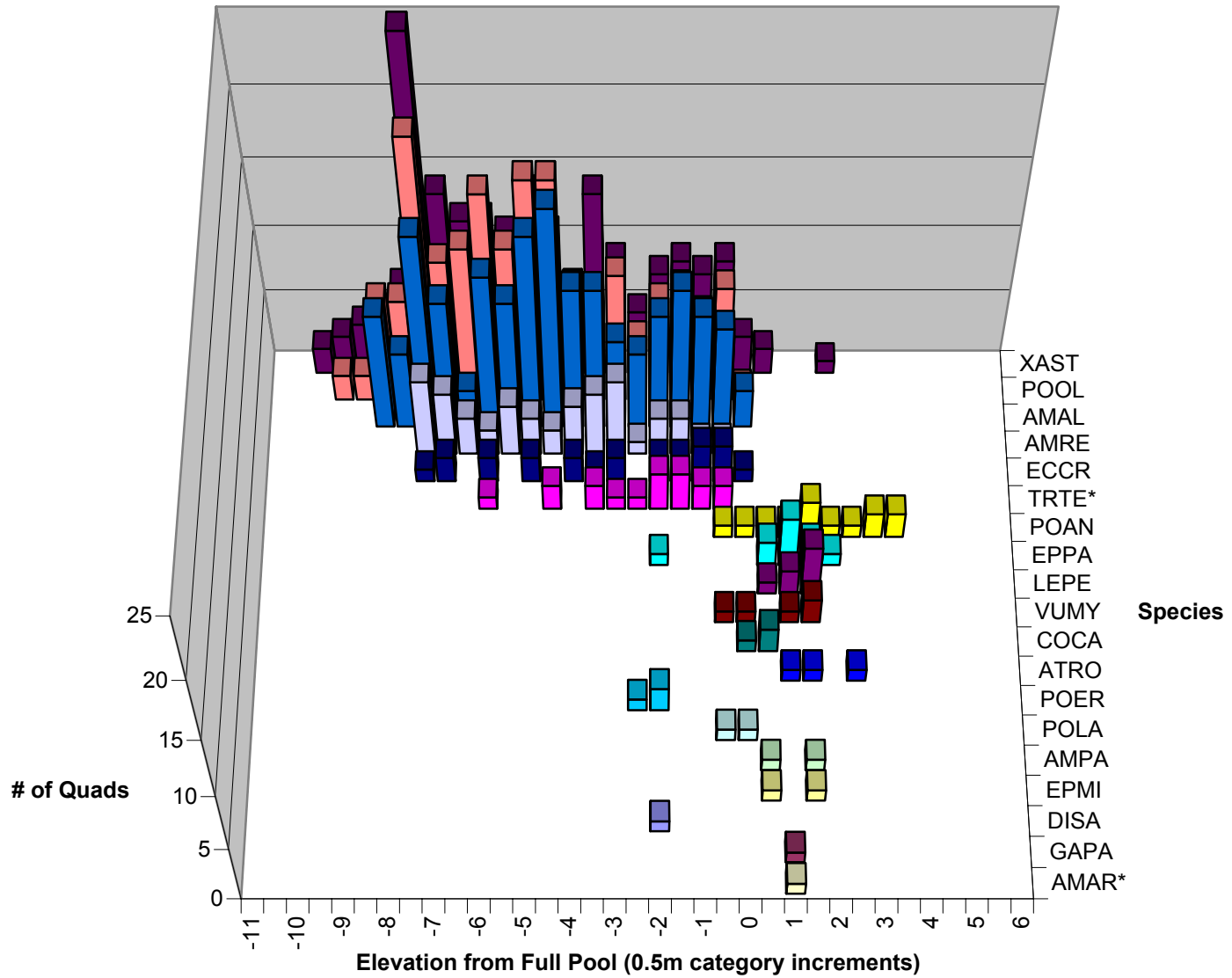
Brownlee Main Reservoir - Elevational Occurrence of Groups



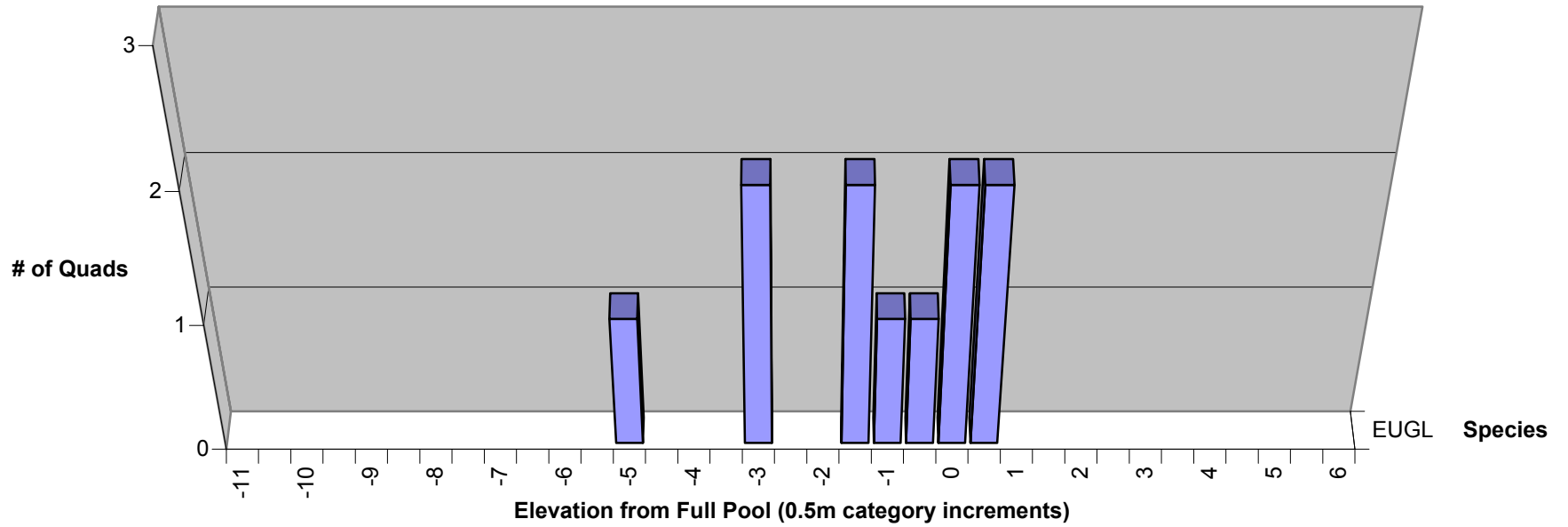
Brownlee Main Reservoir - Elevational Occurrence of HYD species



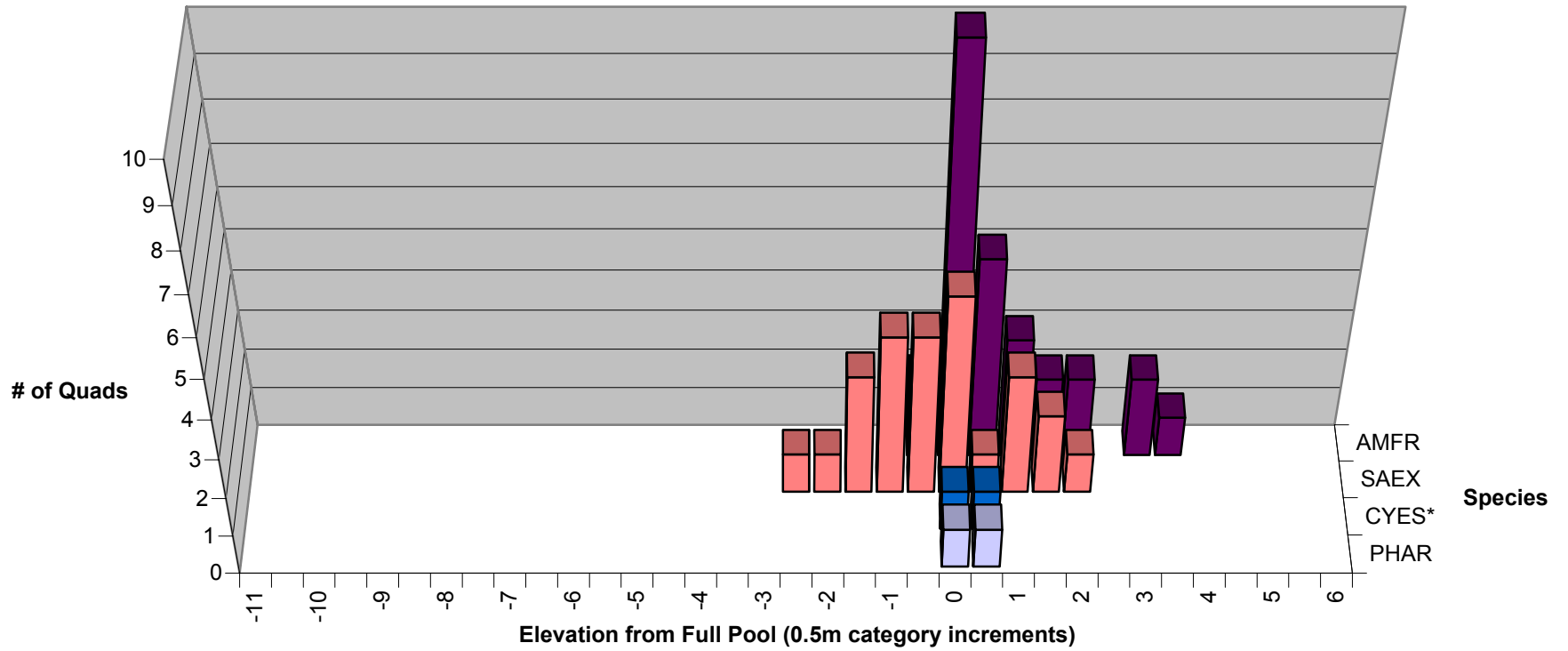
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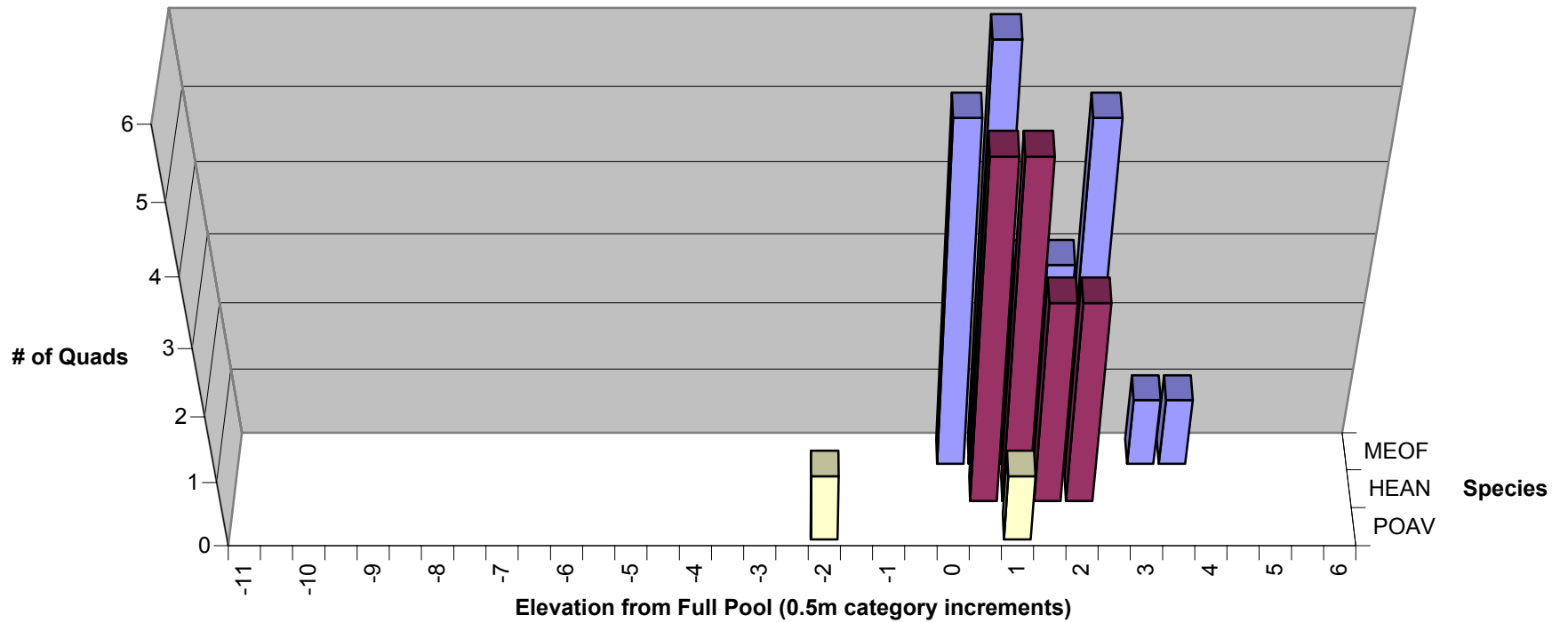
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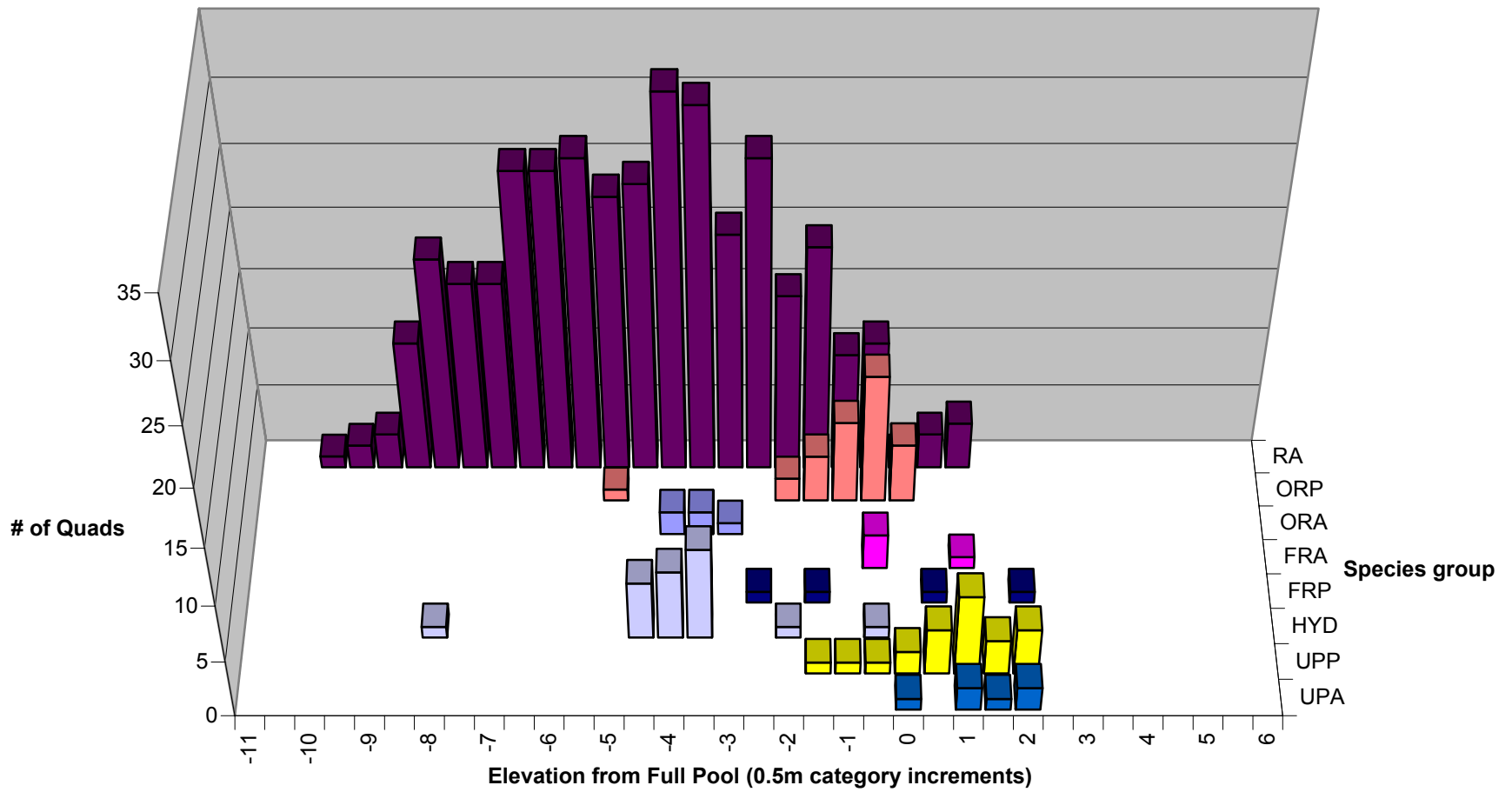
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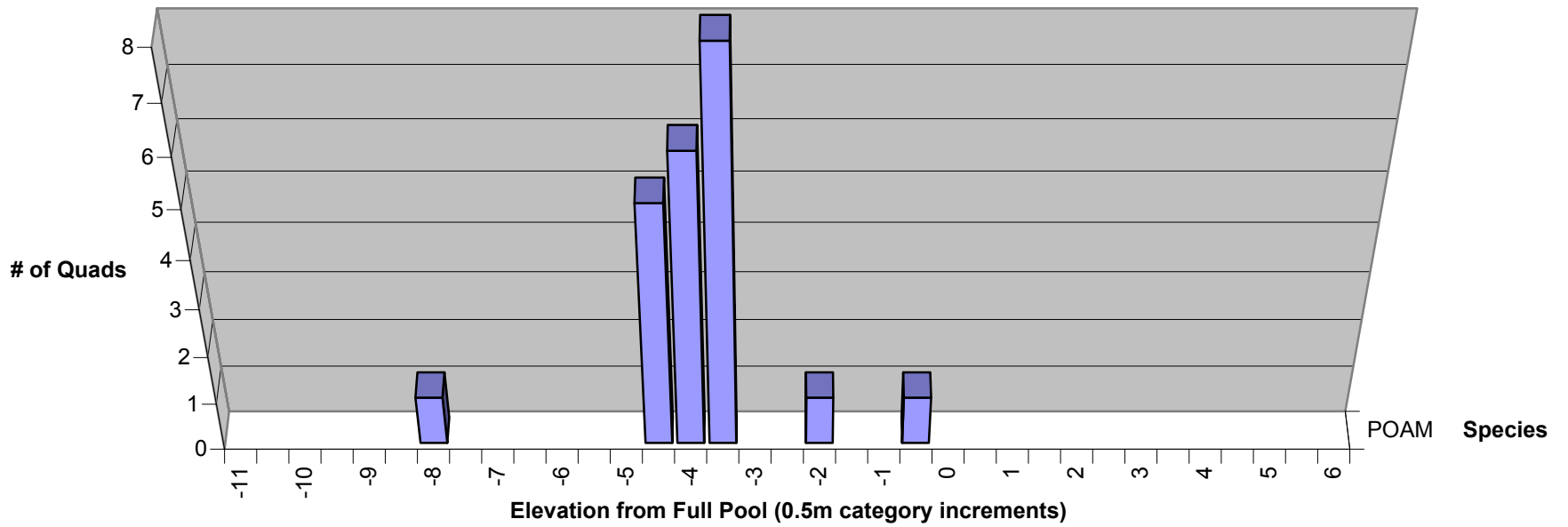
Brownlee Main Reservoir - Elevational Occurrence of FRA species



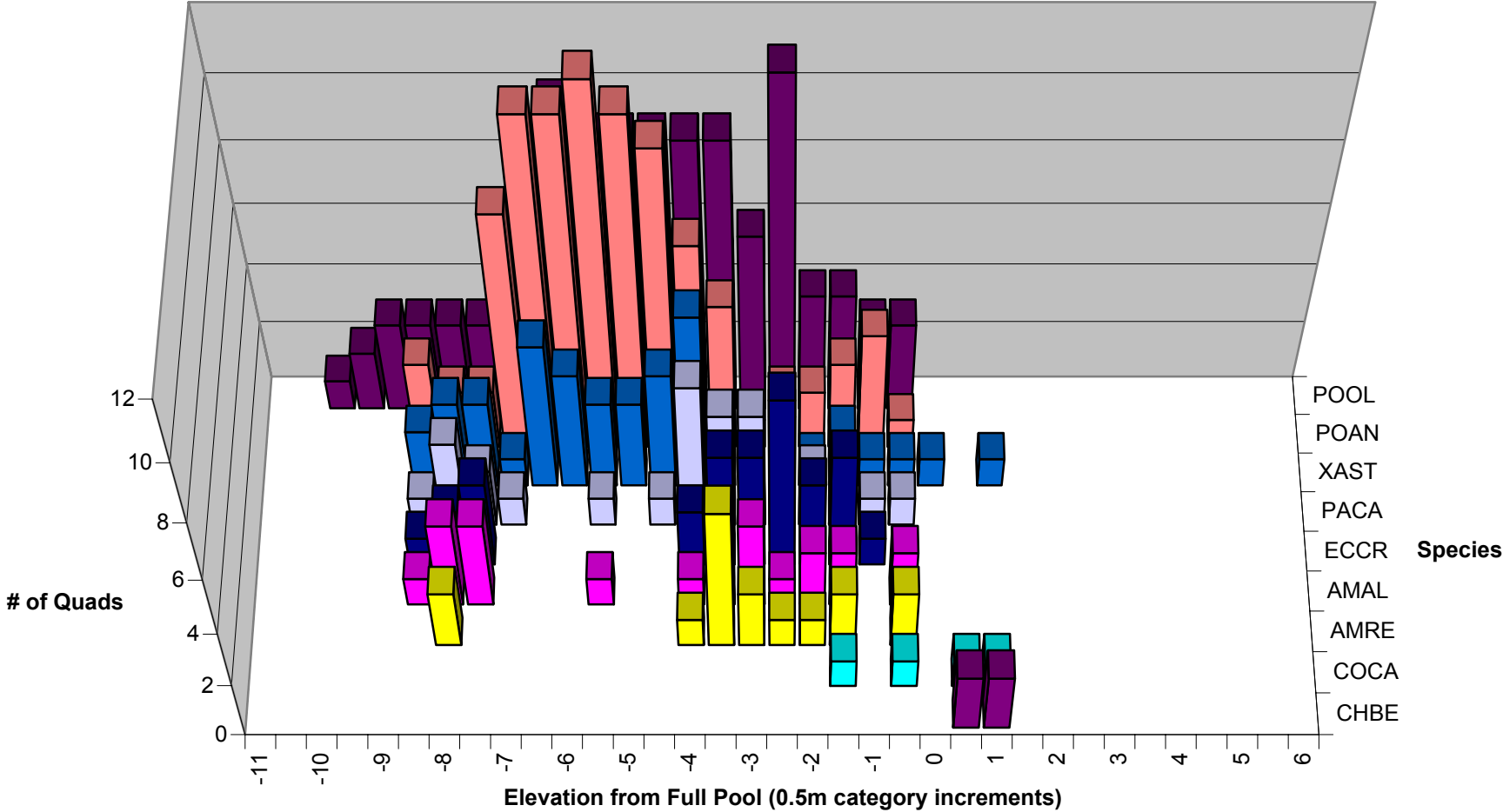
Brownlee Res. - Powder Arm - Elevational Occurrence of Groups



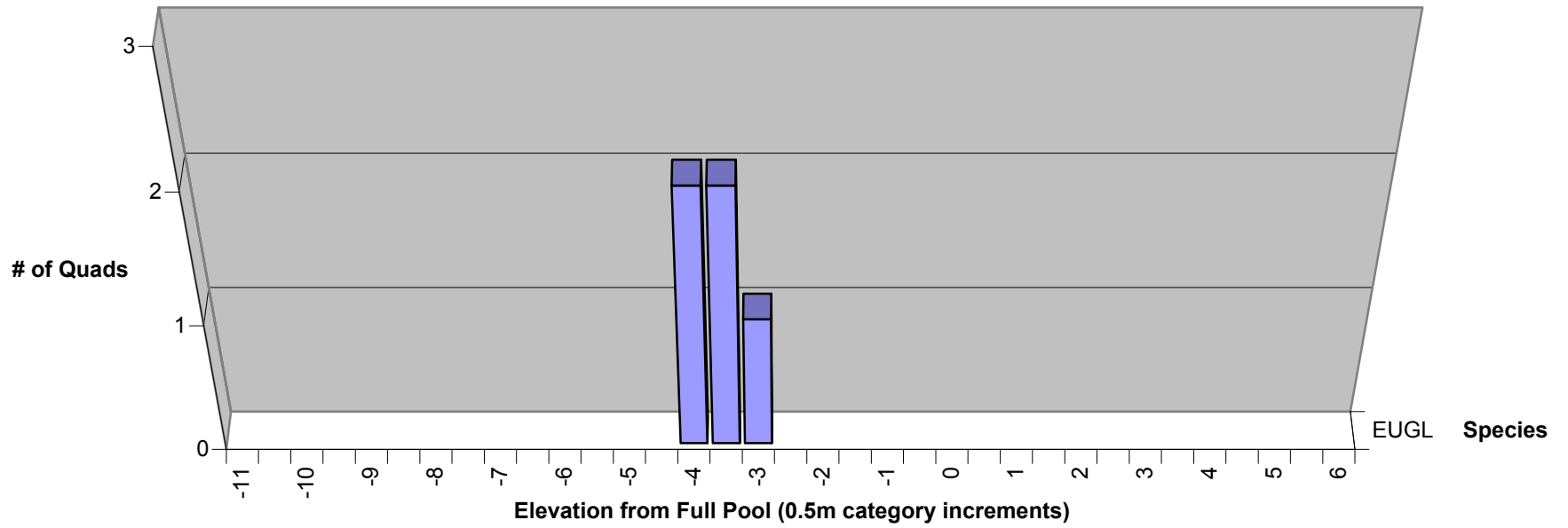
Brownlee Res. - Powder Arm - Elevational Occurrence of HYD species



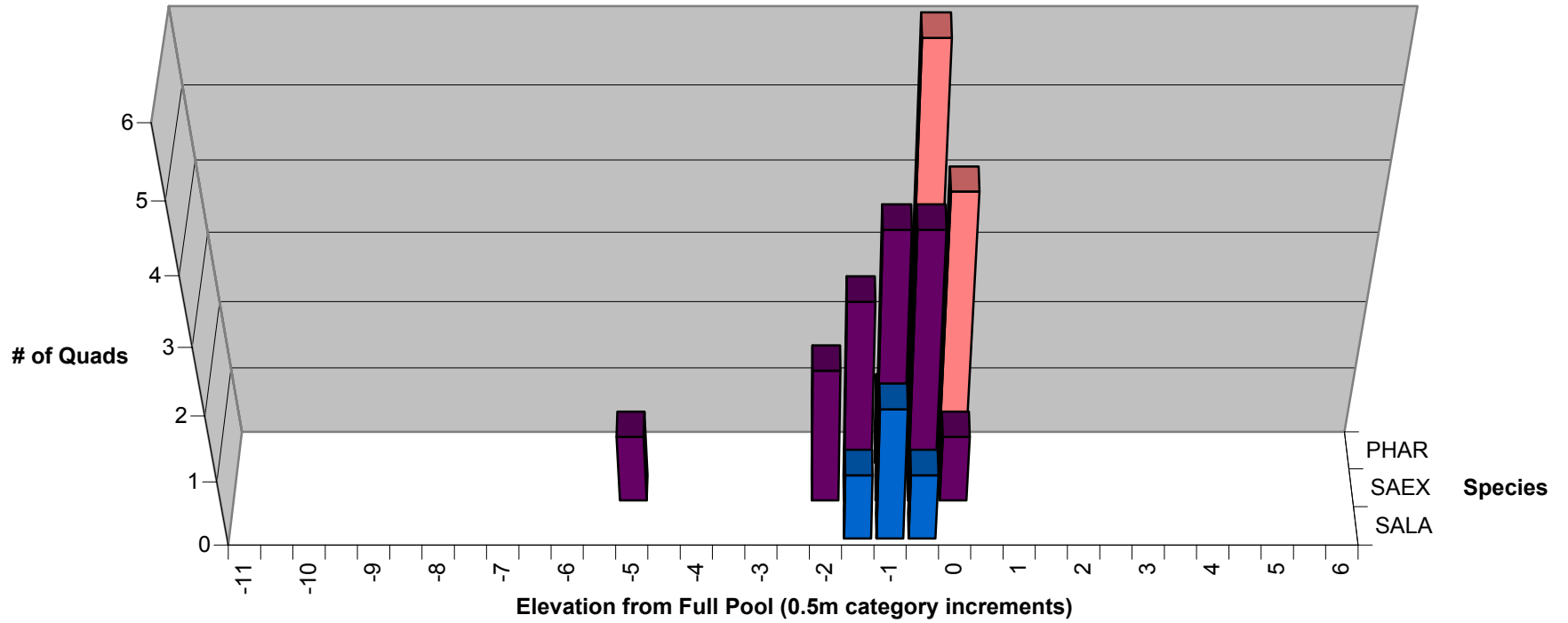
Brownlee Res. - Powder Arm - Elevational Occurrence of RA species



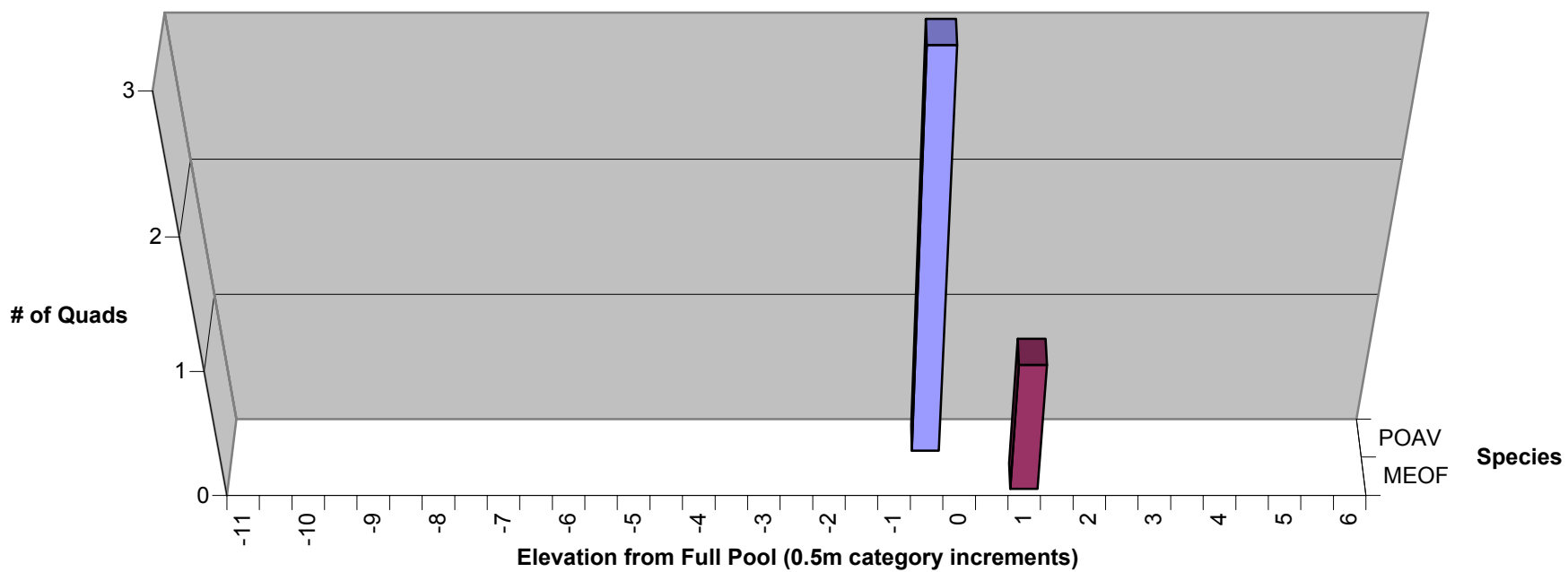
Brownlee Res. - Powder Arm - Elevational Occurrence of ORA species



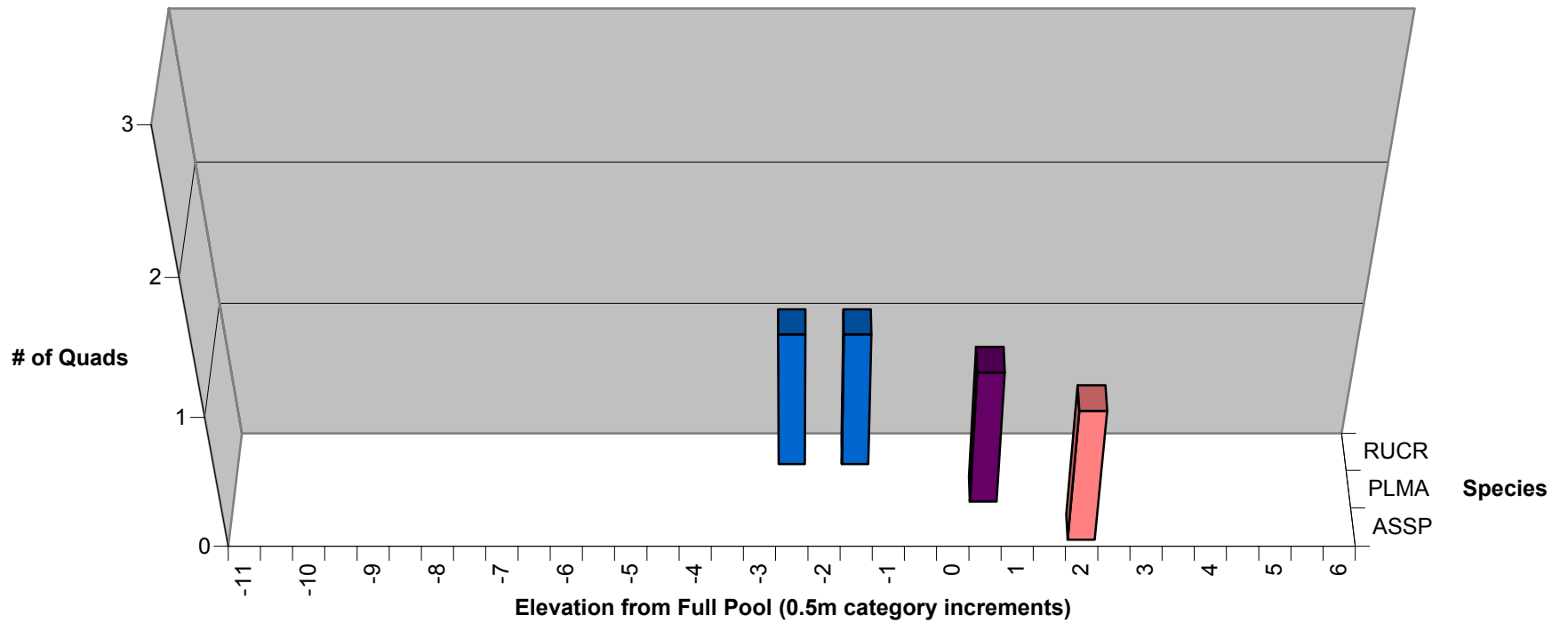
Brownlee Res. - Powder Arm - Elevational Occurrence of ORP species



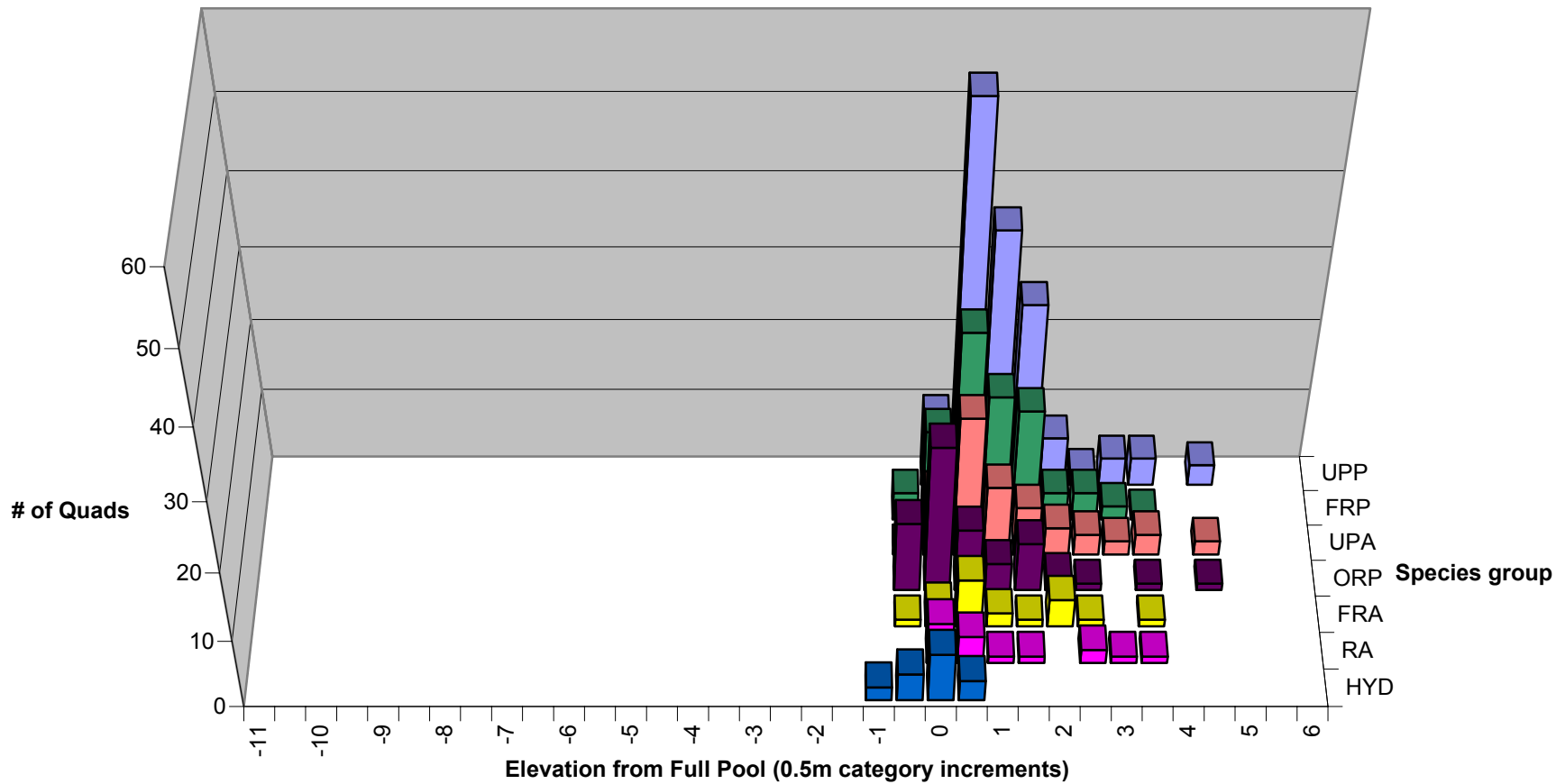
Brownlee Res. - Powder Arm - Elevational Occurrence of FRA species



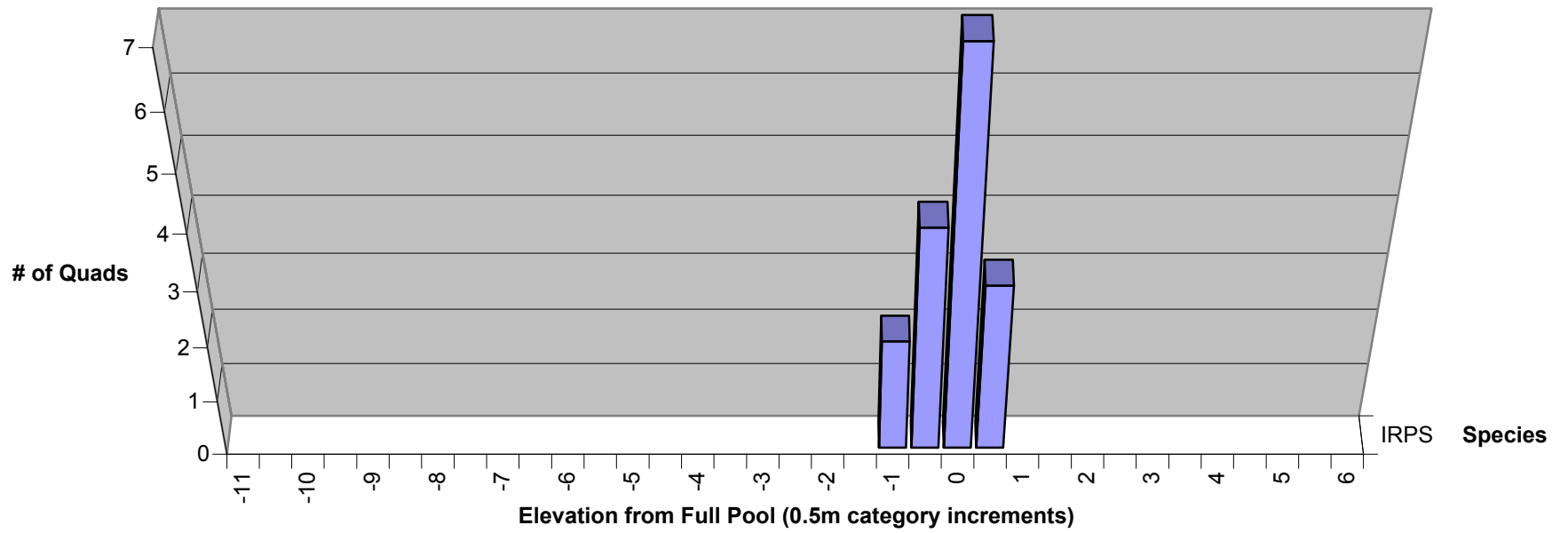
Brownlee Res. - Powder Arm - Elevational Occurrence of FRP species



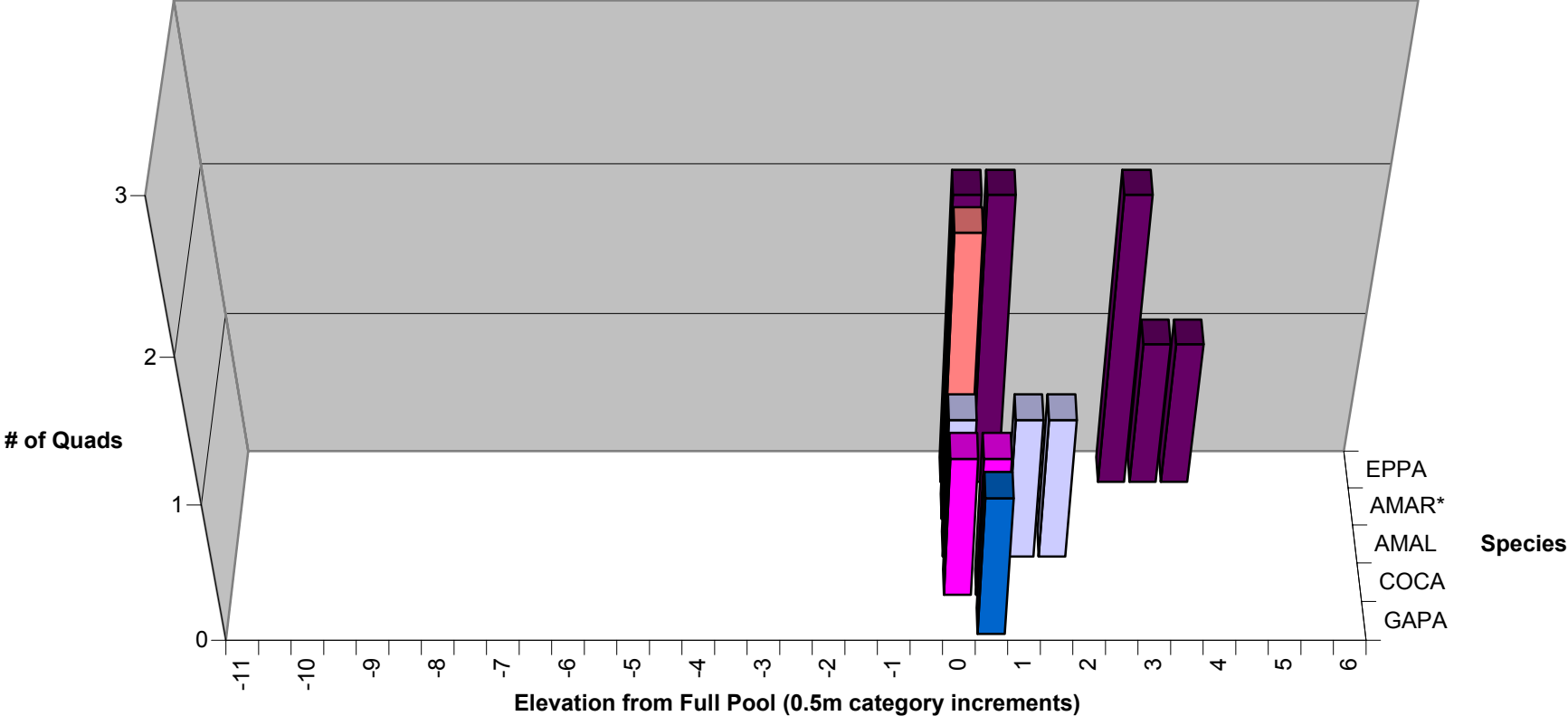
Oxbow Main Reservoir - Elevational Occurrence of Groups



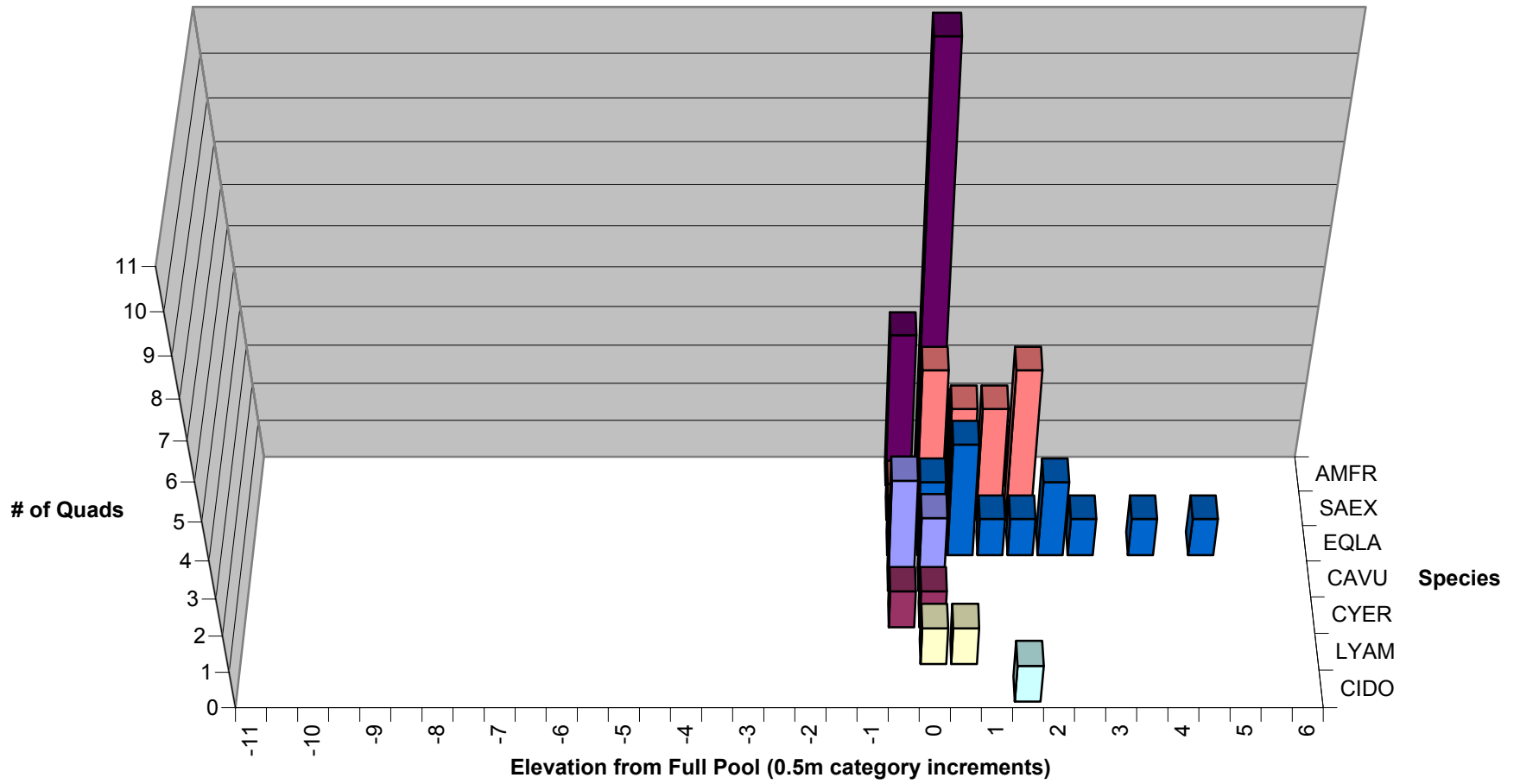
Oxbow Main Reservoir - Elevational Occurrence of HYD species



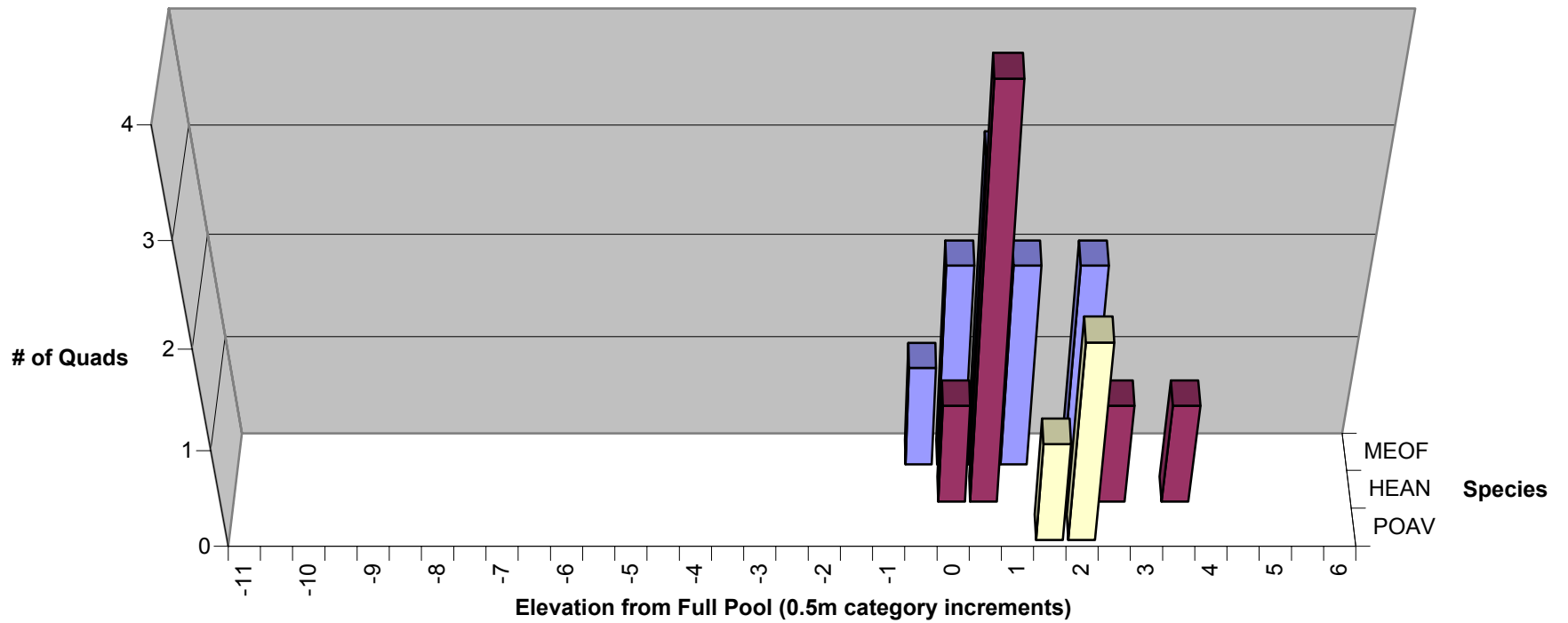
Oxbow Main Reservoir - Elevational Occurrence of RA species



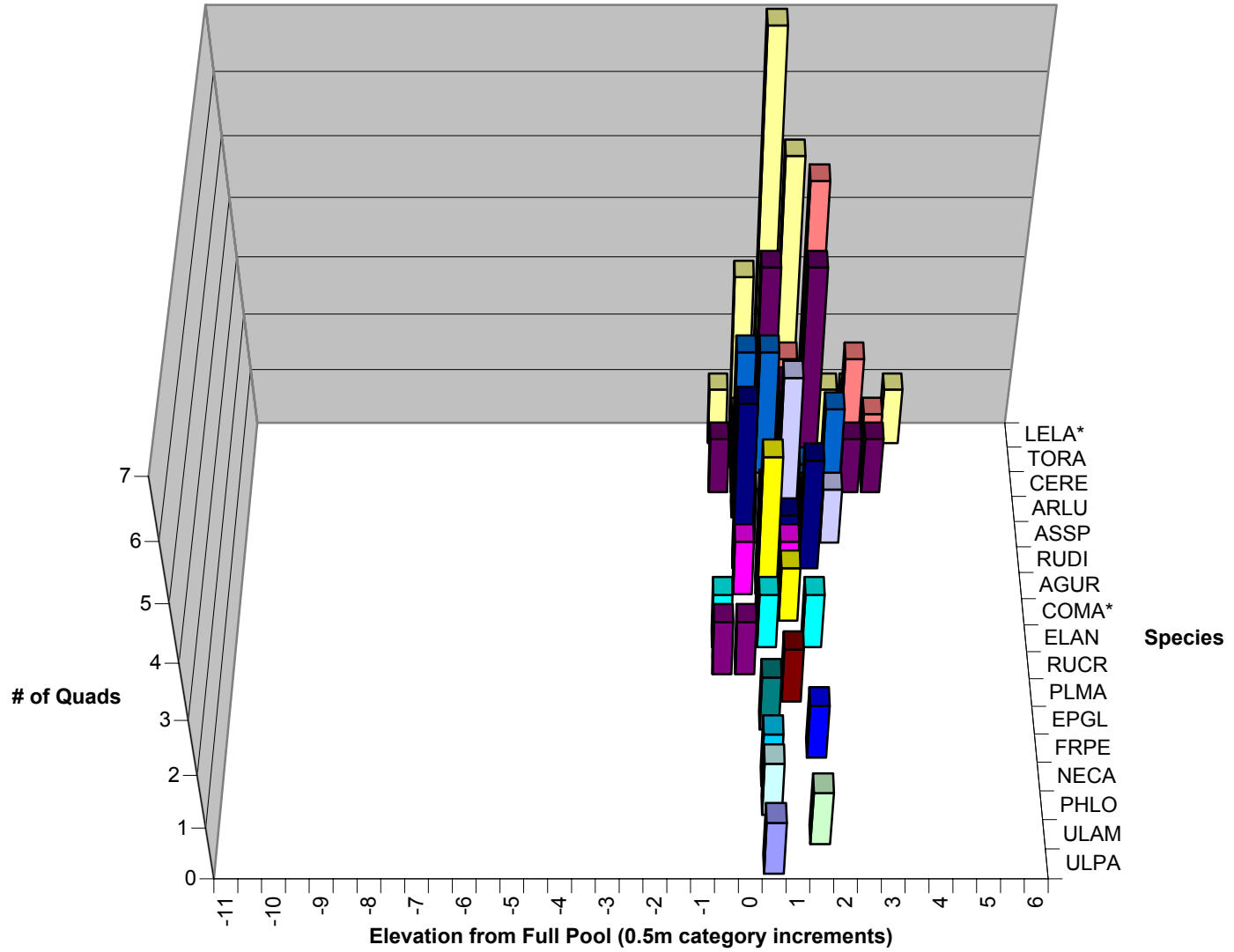
Oxbow Main Reservoir - Elevational Occurrence of ORP species



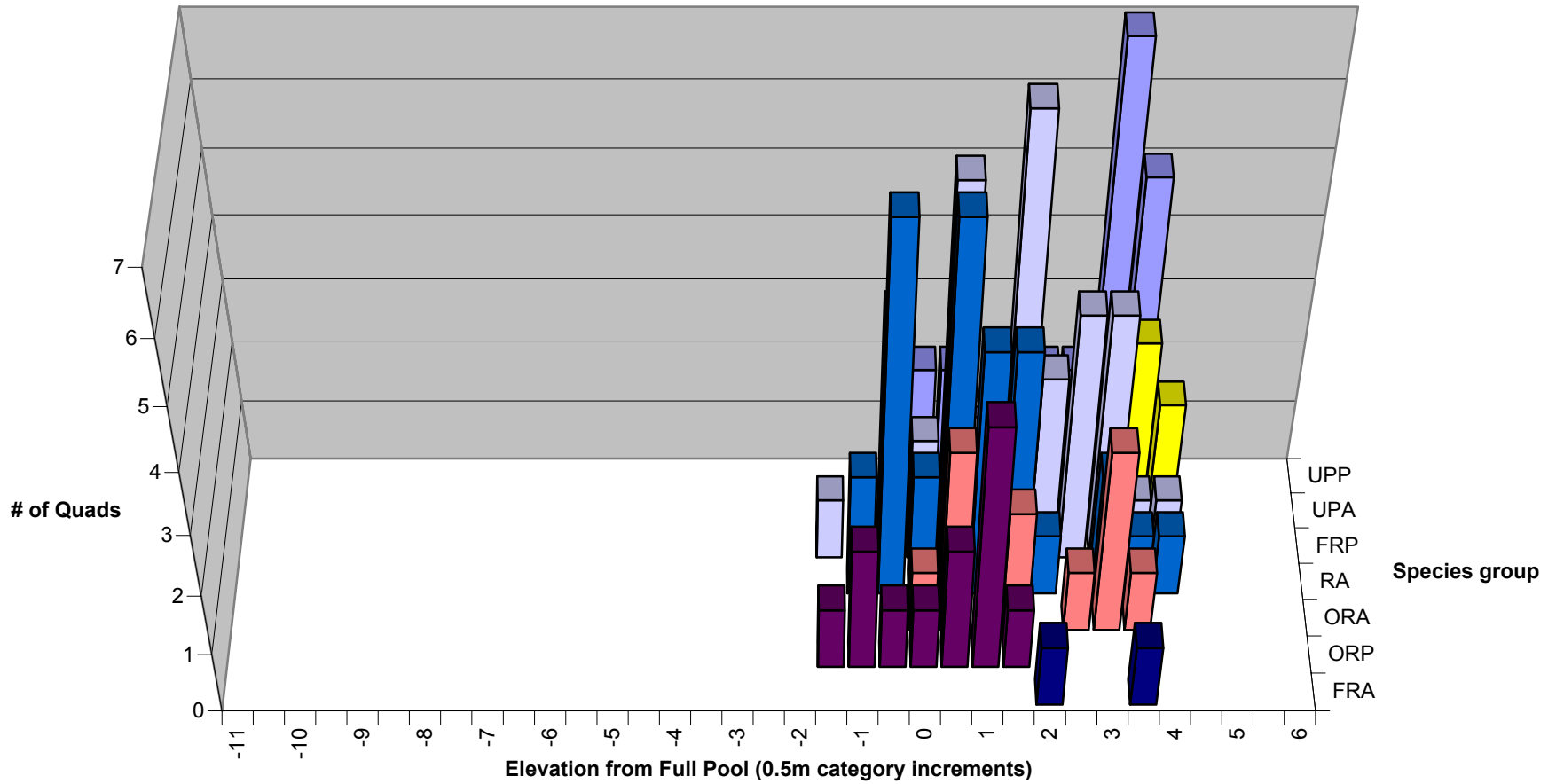
Oxbow Main Reservoir - Elevational Occurrence of FRA species



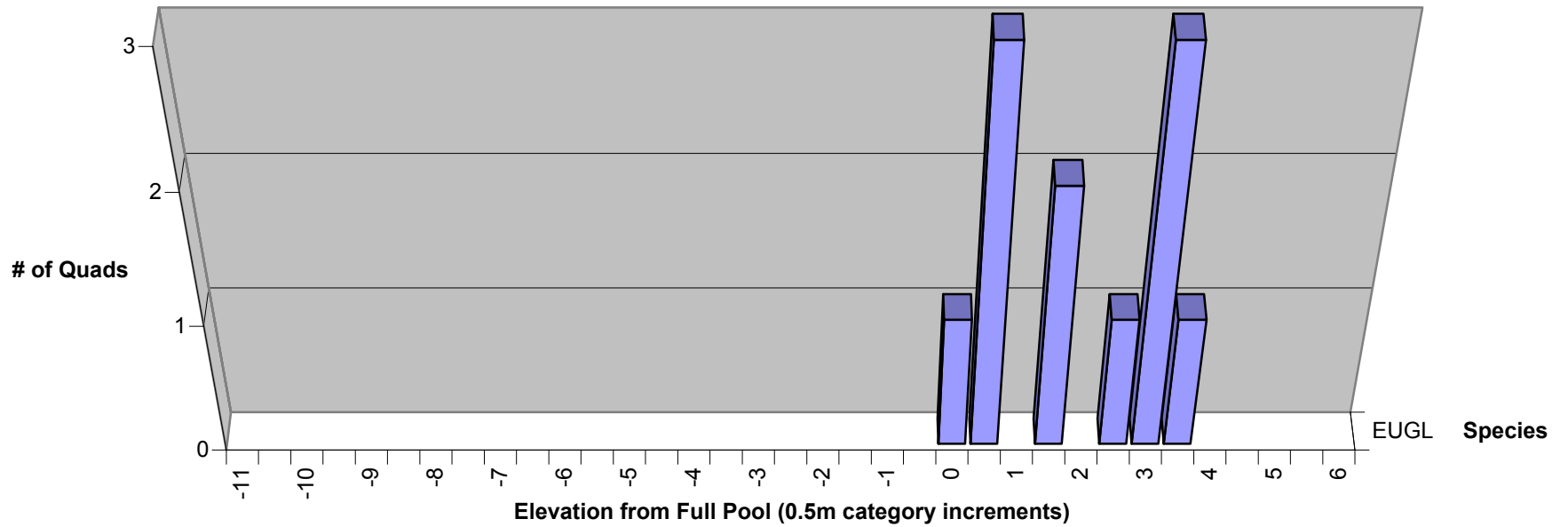
Oxbow Main Reservoir - Elevational Occurrence of FRP species



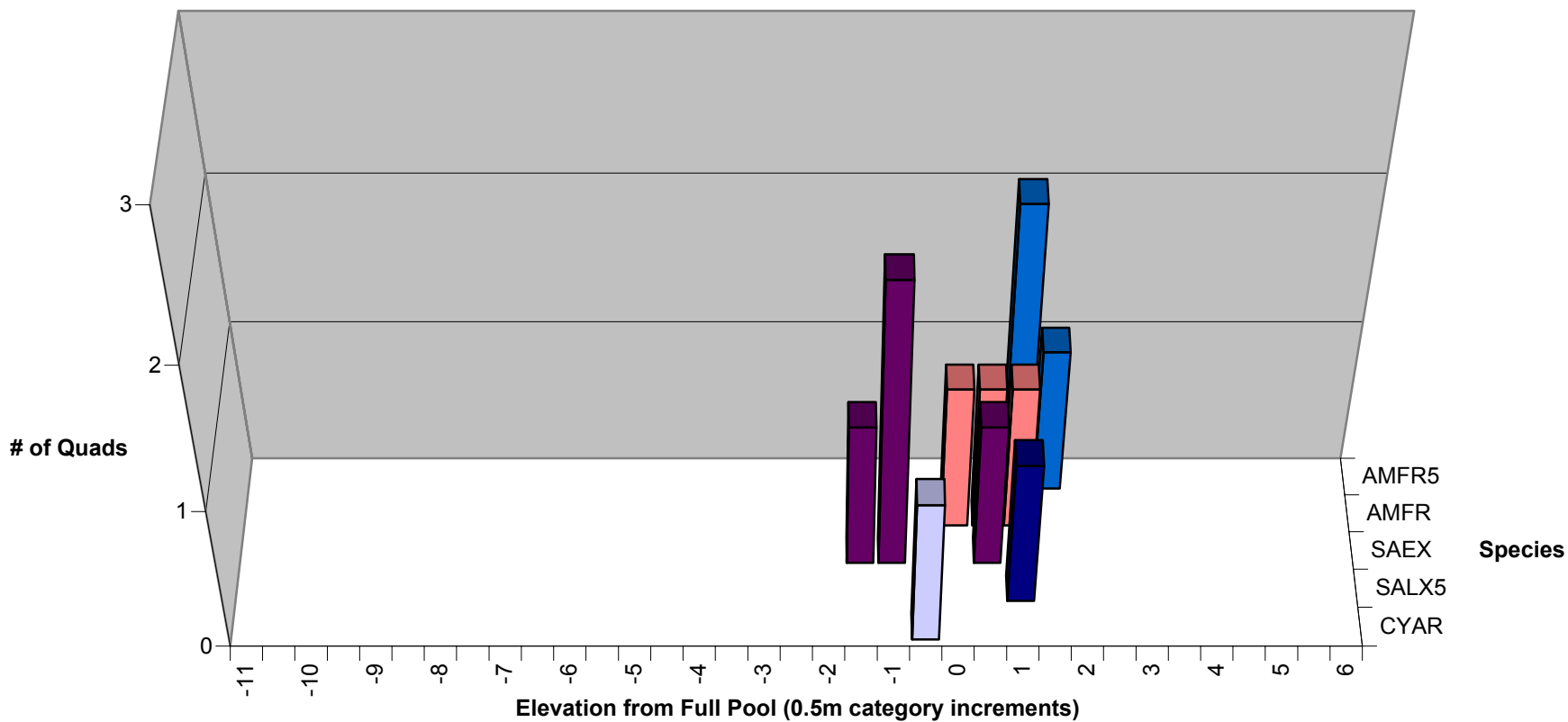
Hells Canyon Reservoir Bypass - Elevational Occurrence of Groups



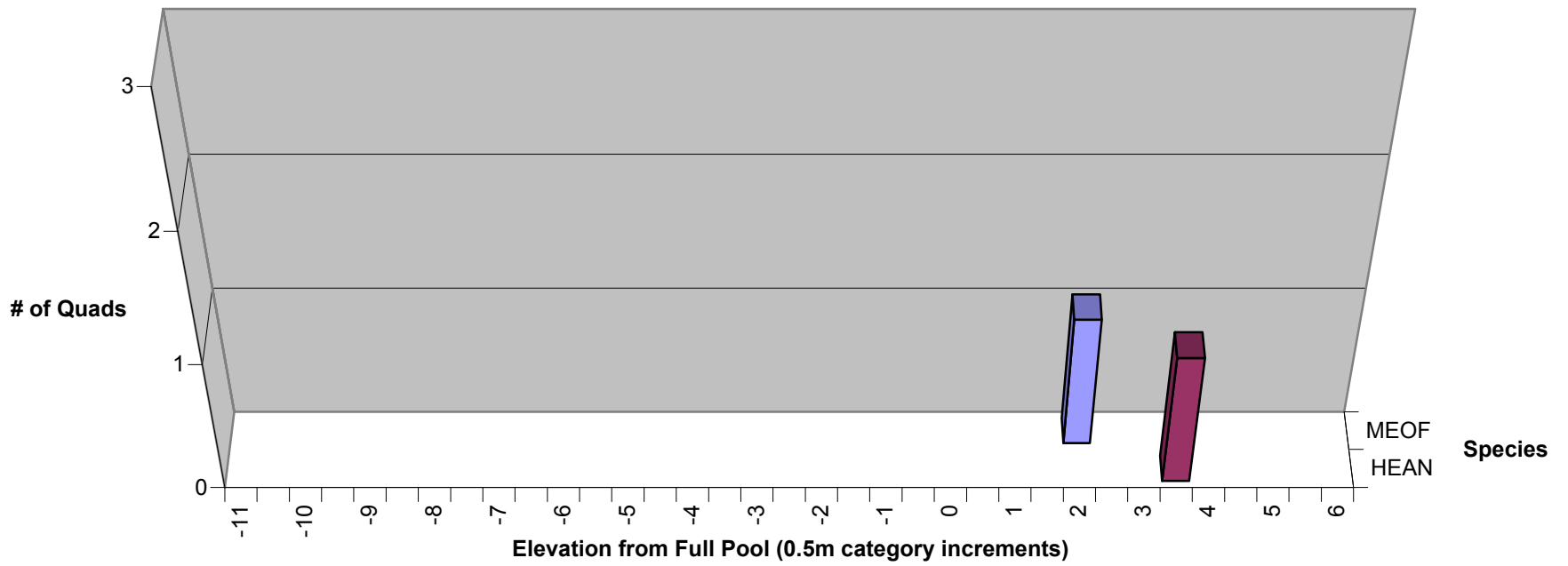
Hells Canyon Reservoir Bypass - Elevational Occurrence of ORA species



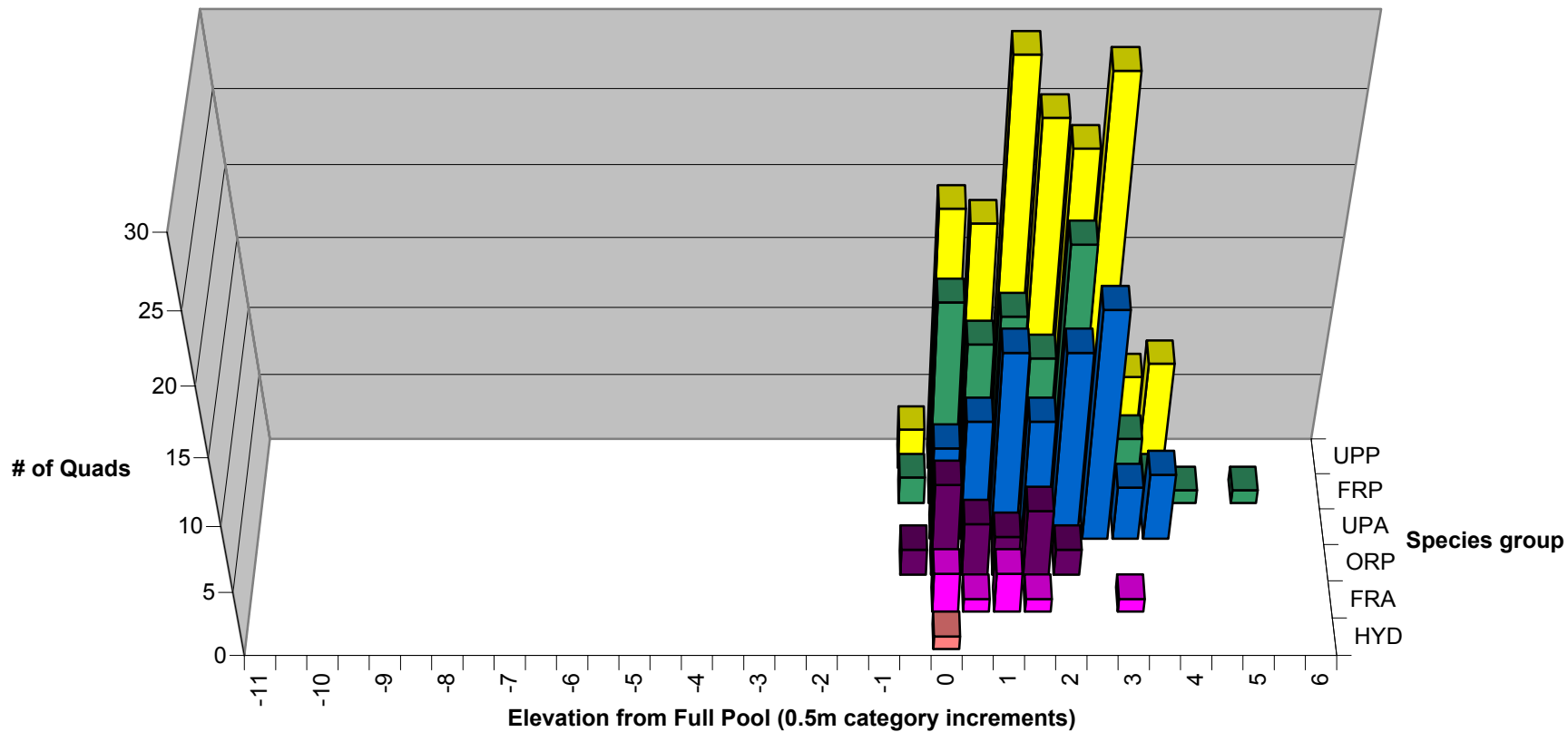
Hells Canyon Reservoir Bypass - Elevational Occurrence of ORP species



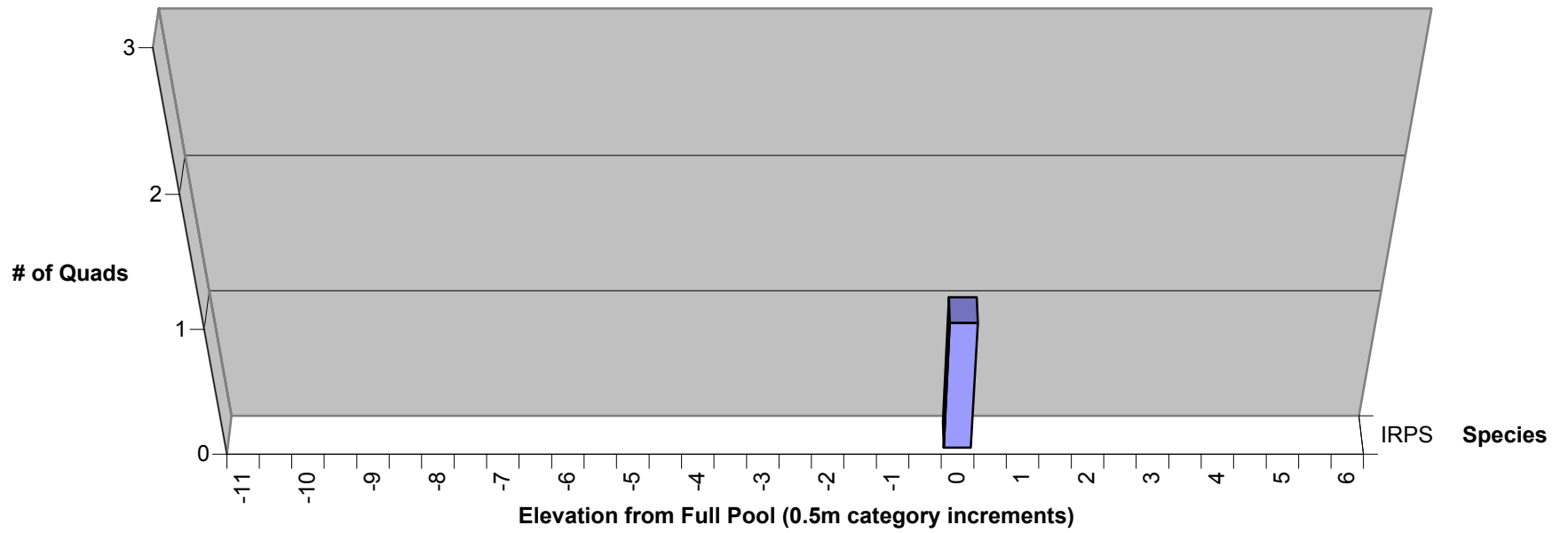
Hells Canyon Reservoir Bypass - Elevational Occurrence of FRA species



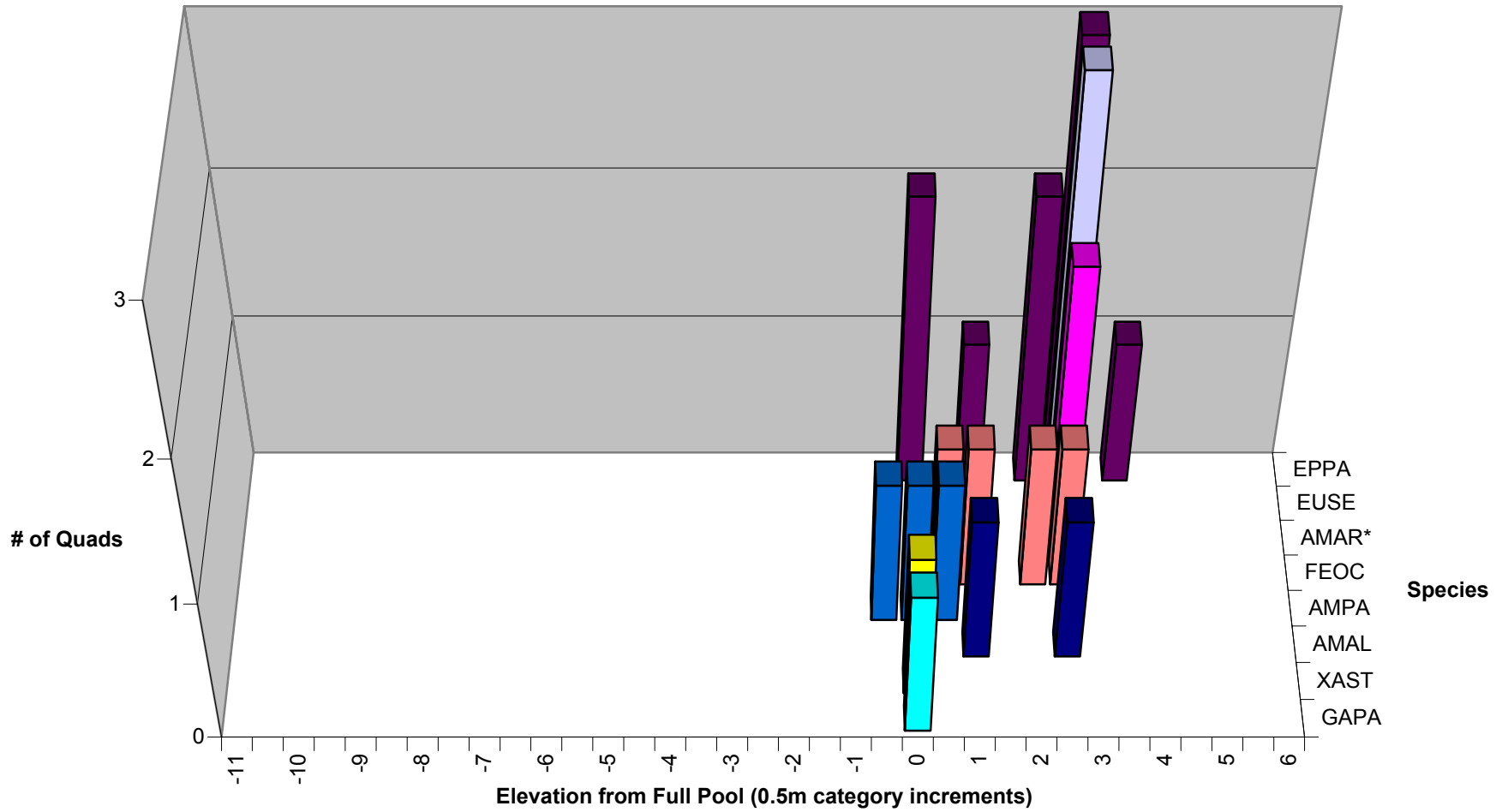
Hells Canyon Main Reservoir - Elevational Occurrence of Groups



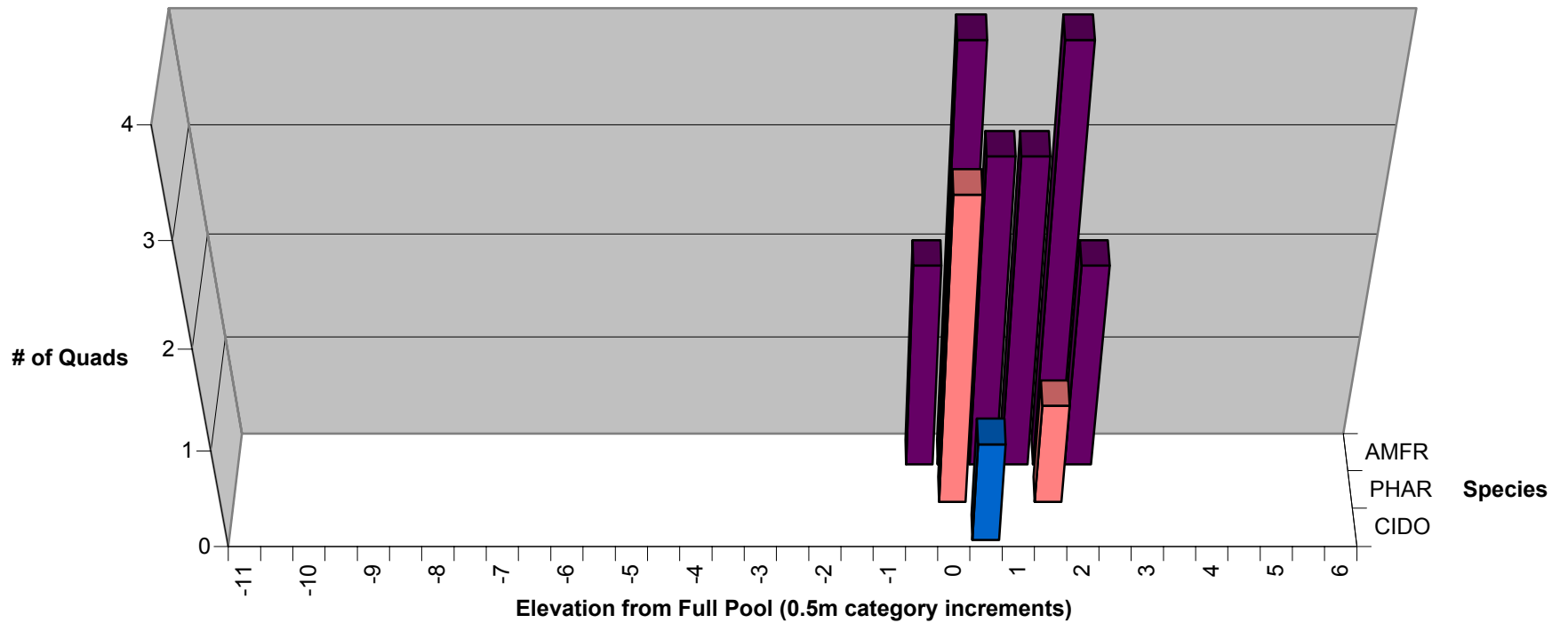
Hells Canyon Main Reservoir - Elevational Occurrence of HYD species



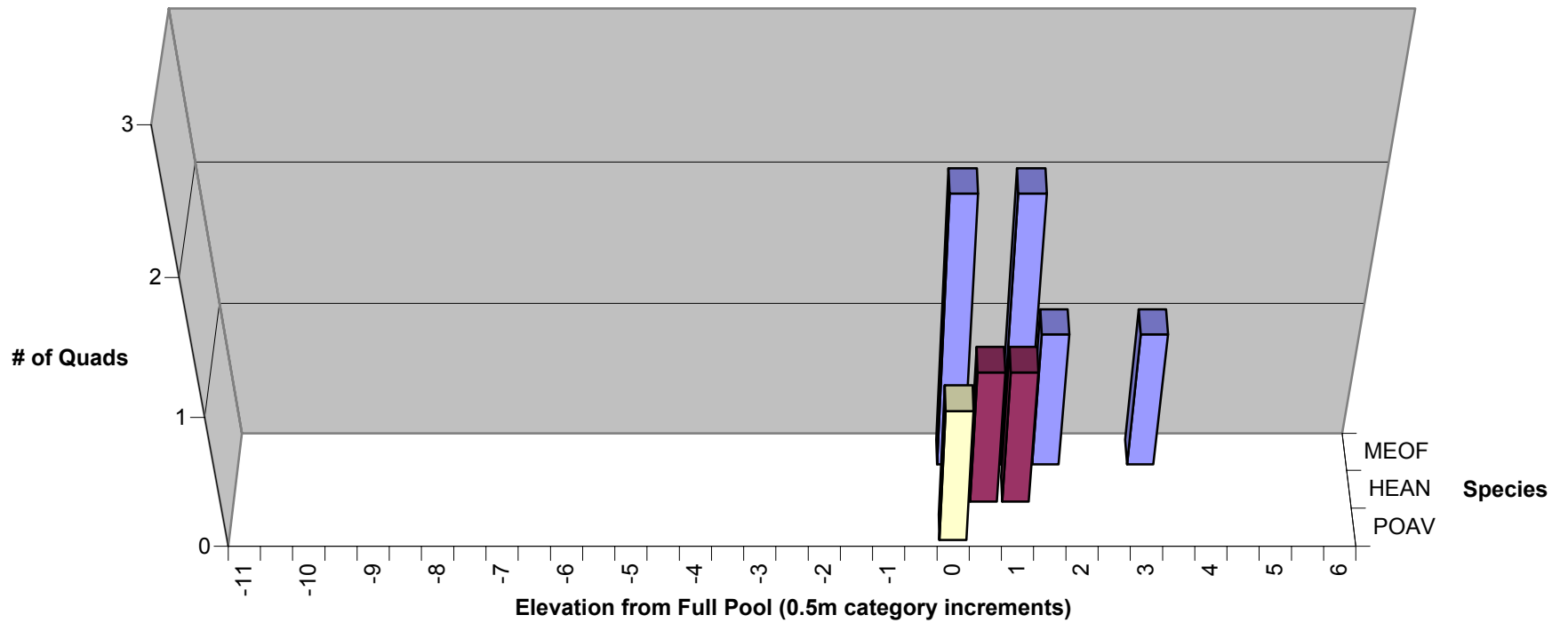
Hells Canyon Main Reservoir - Elevational Occurrence of RA species



Hells Canyon Main Reservoir - Elevational Occurrence of ORP species



Hells Canyon Main Reservoir - Elevational Occurrence of FRA species

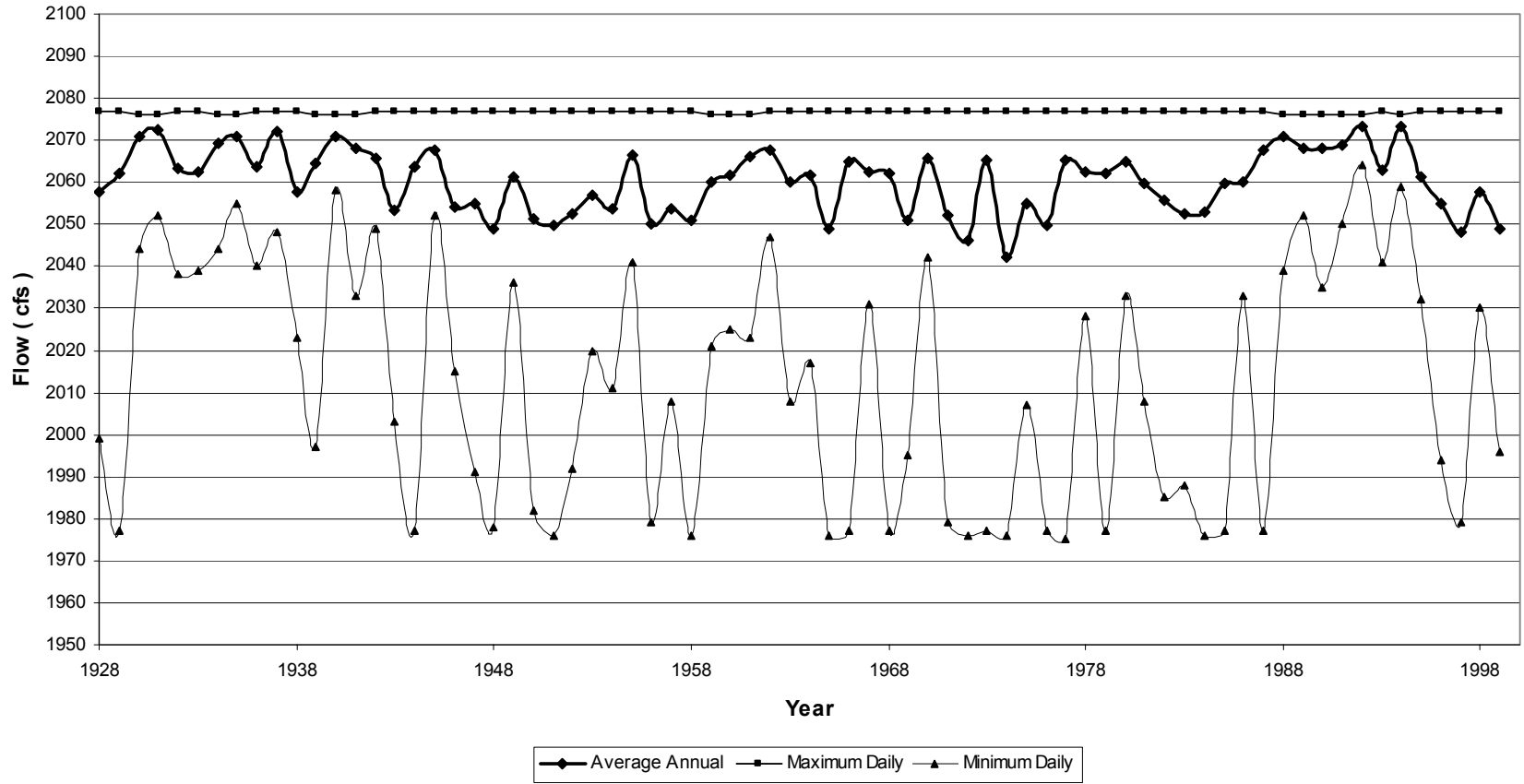


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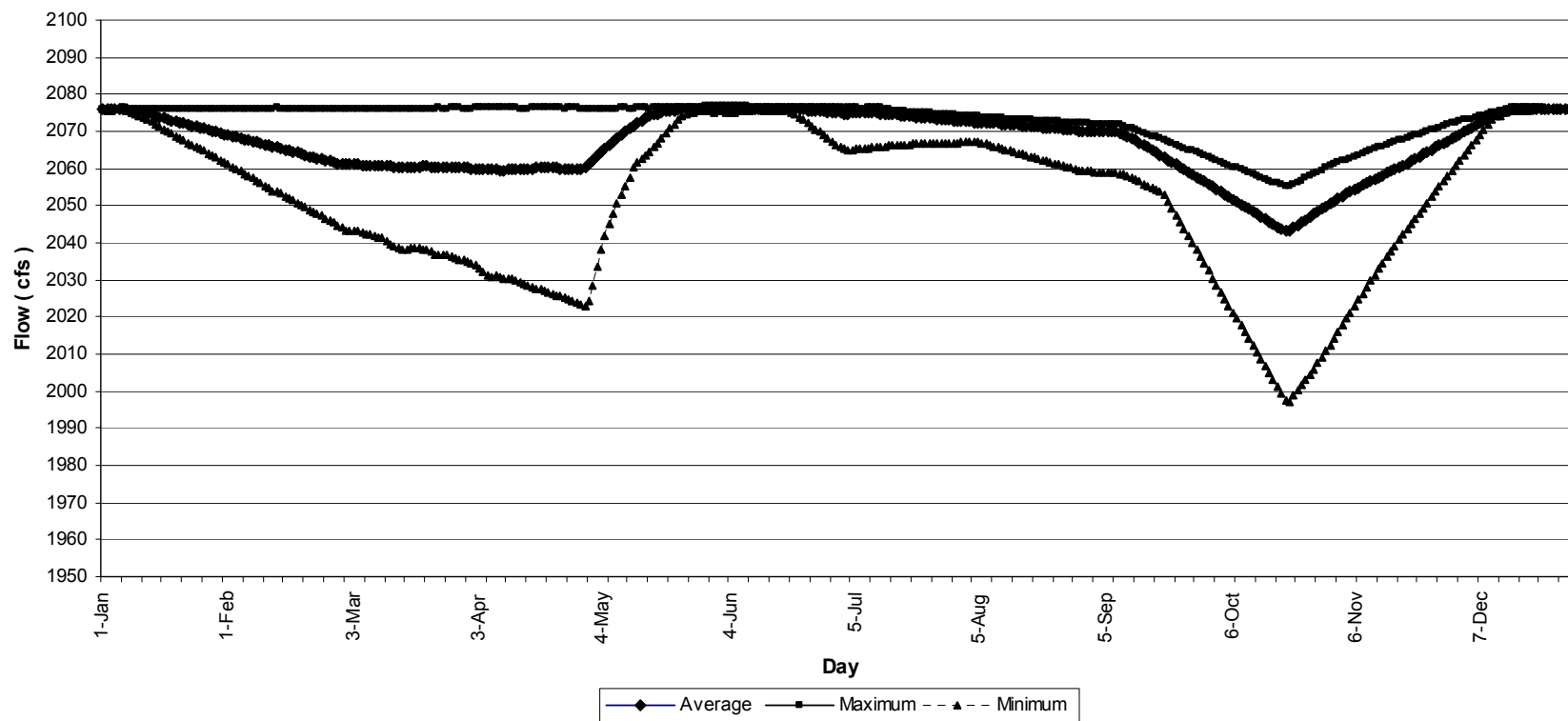
Appendix 3.5. Scenario Water Level Fluctuations (Reservoirs)

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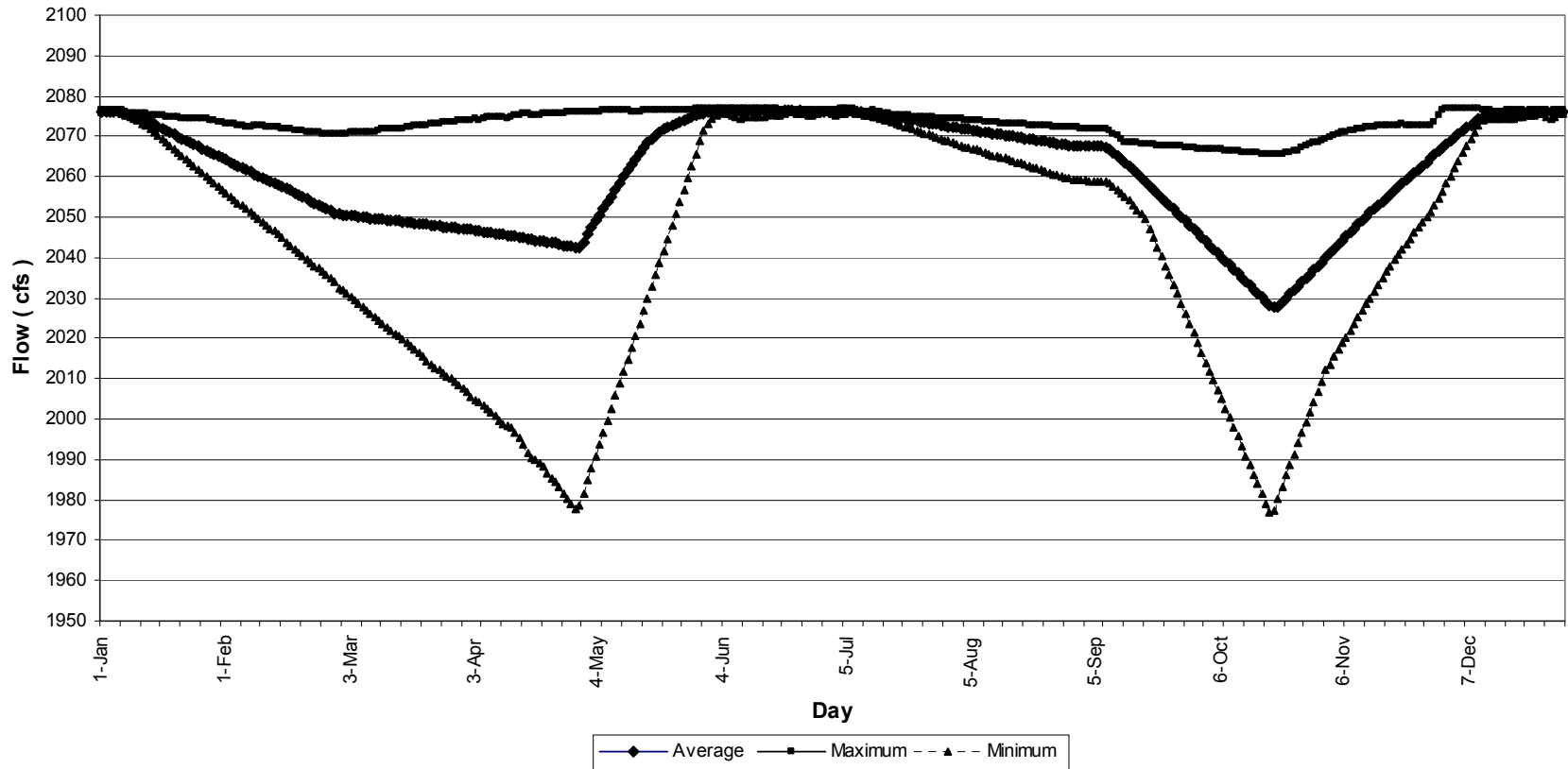
Proposed Water Surface Elevation at Brownlee Reservoir



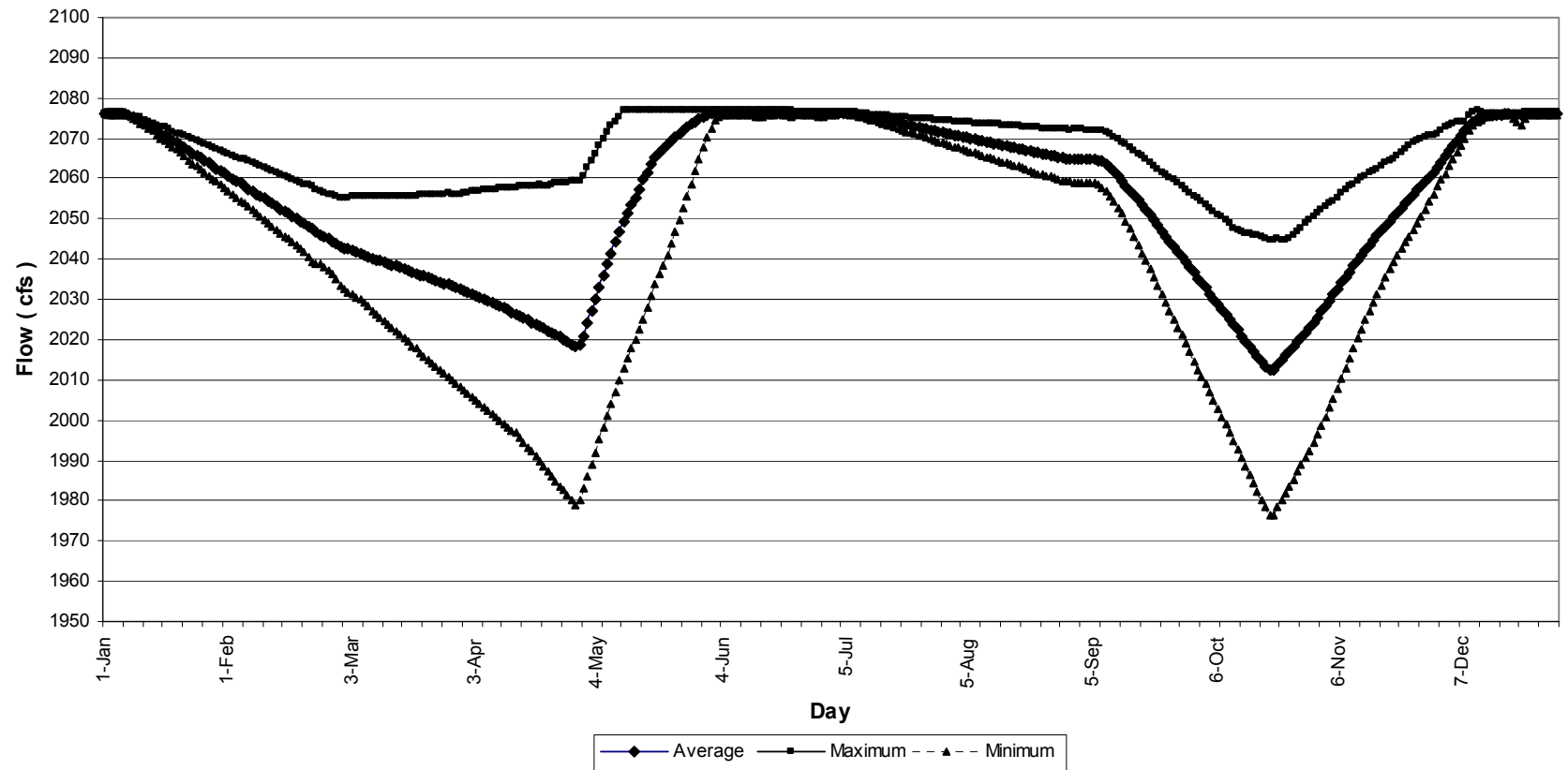
Brownlee Reservoir Proposed Water Surface Elevation - From 1930 to 1939



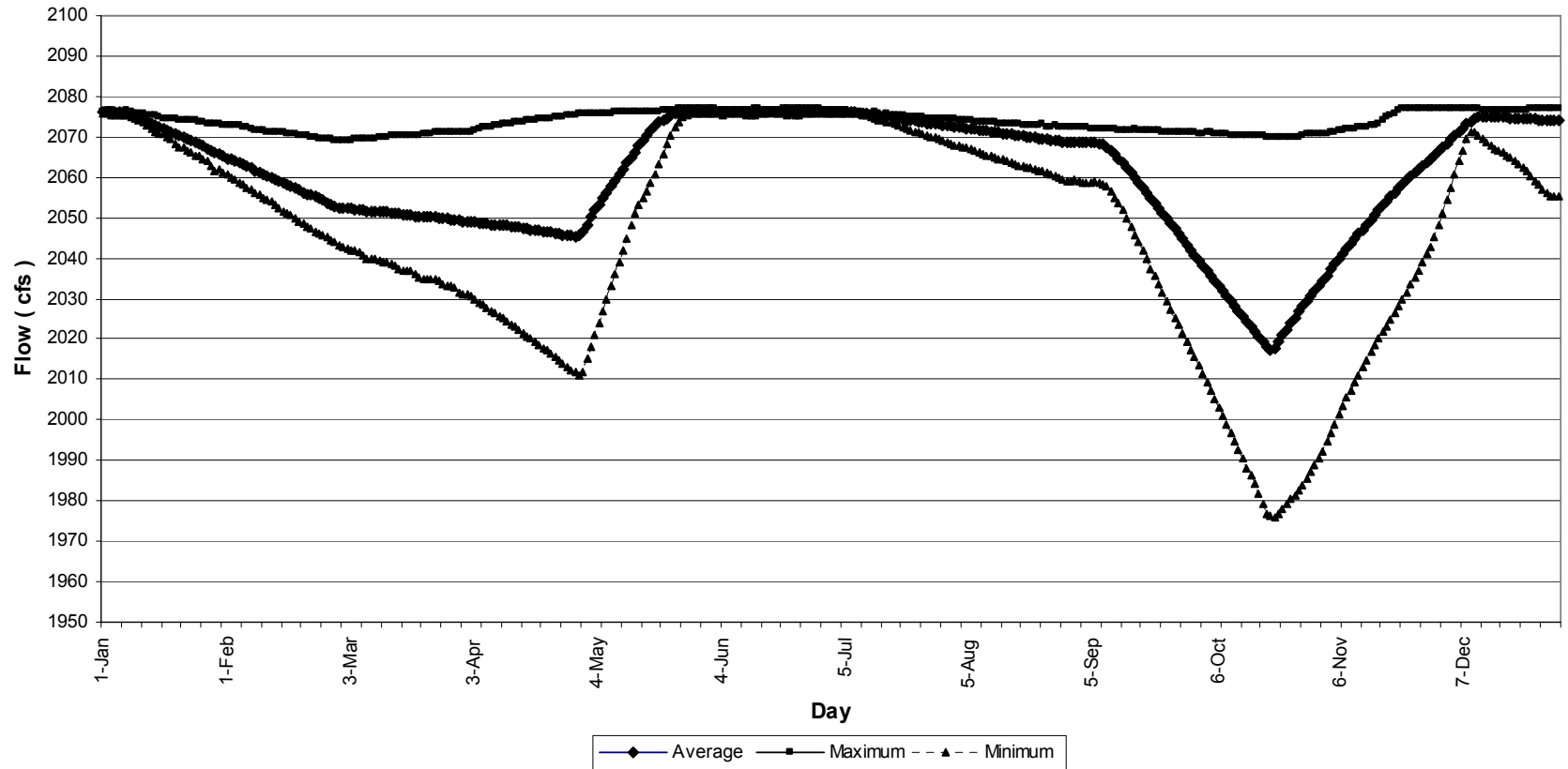
Brownlee Reservoir Proposed Water Surface Elevation - From 1940 to 1949



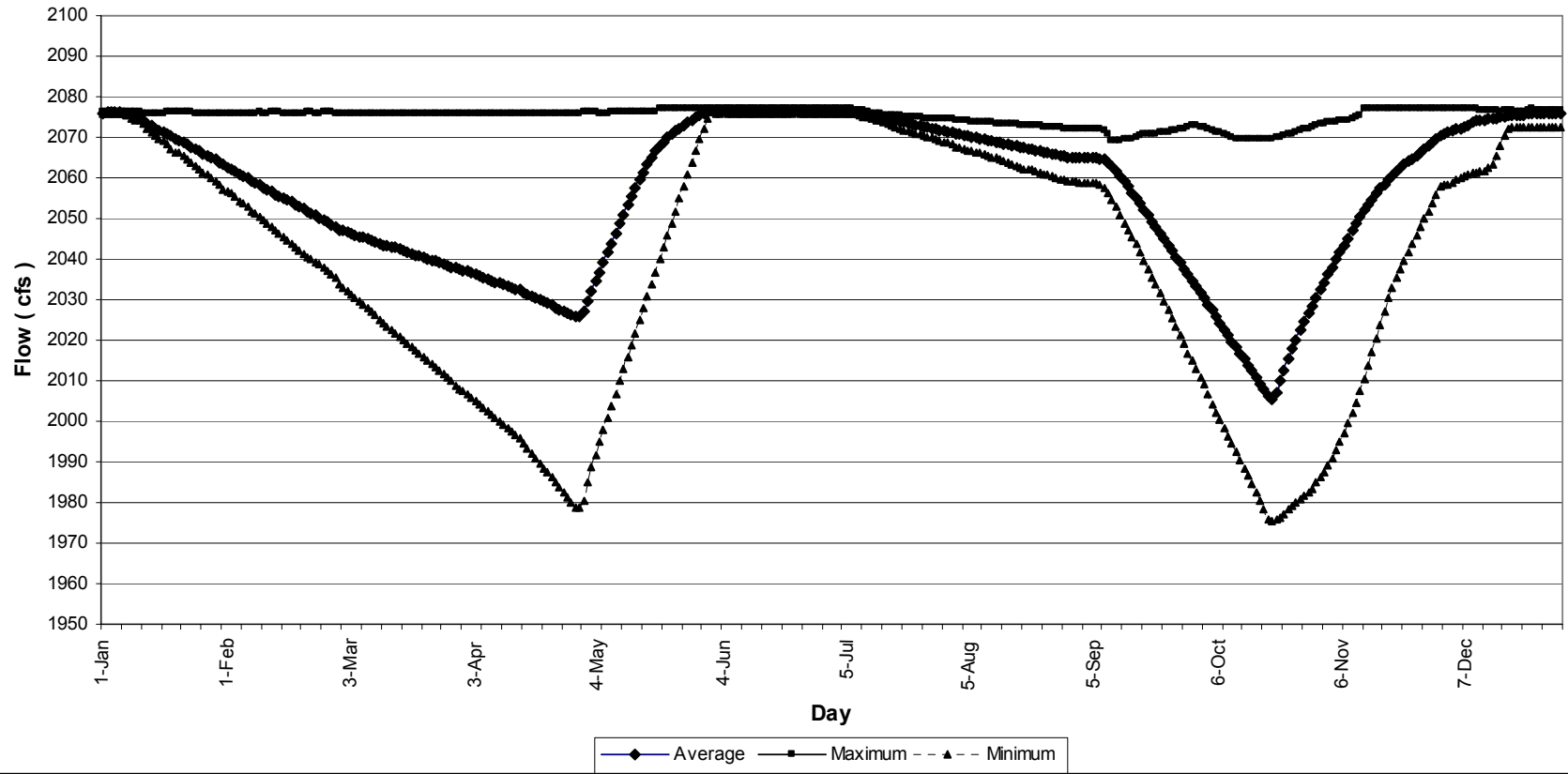
Brownlee Reservoir Proposed Water Surface Elevation - From 1950 to 1959



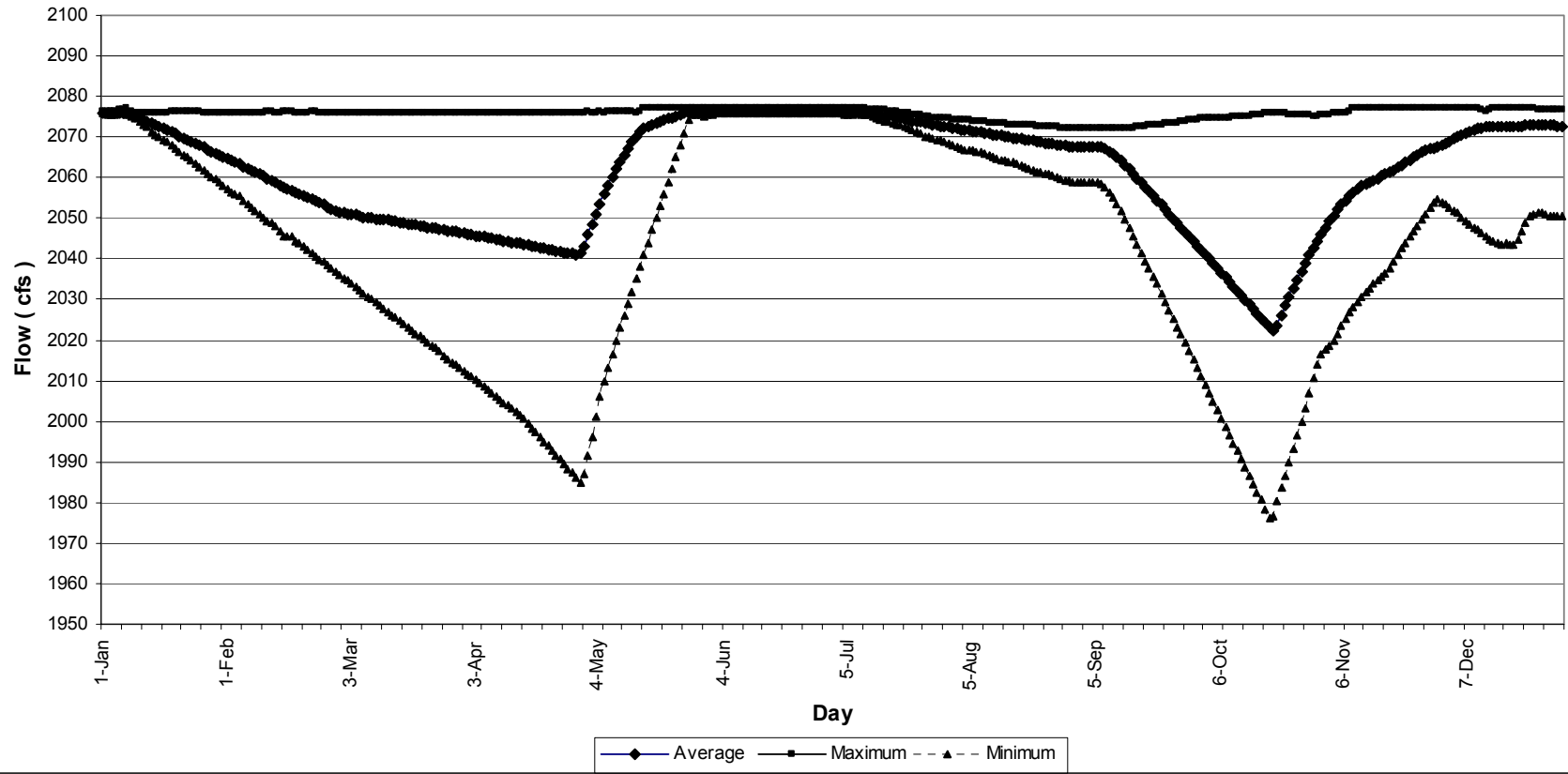
Brownlee Reservoir Proposed Water Surface Elevation - From 1960 to 1969



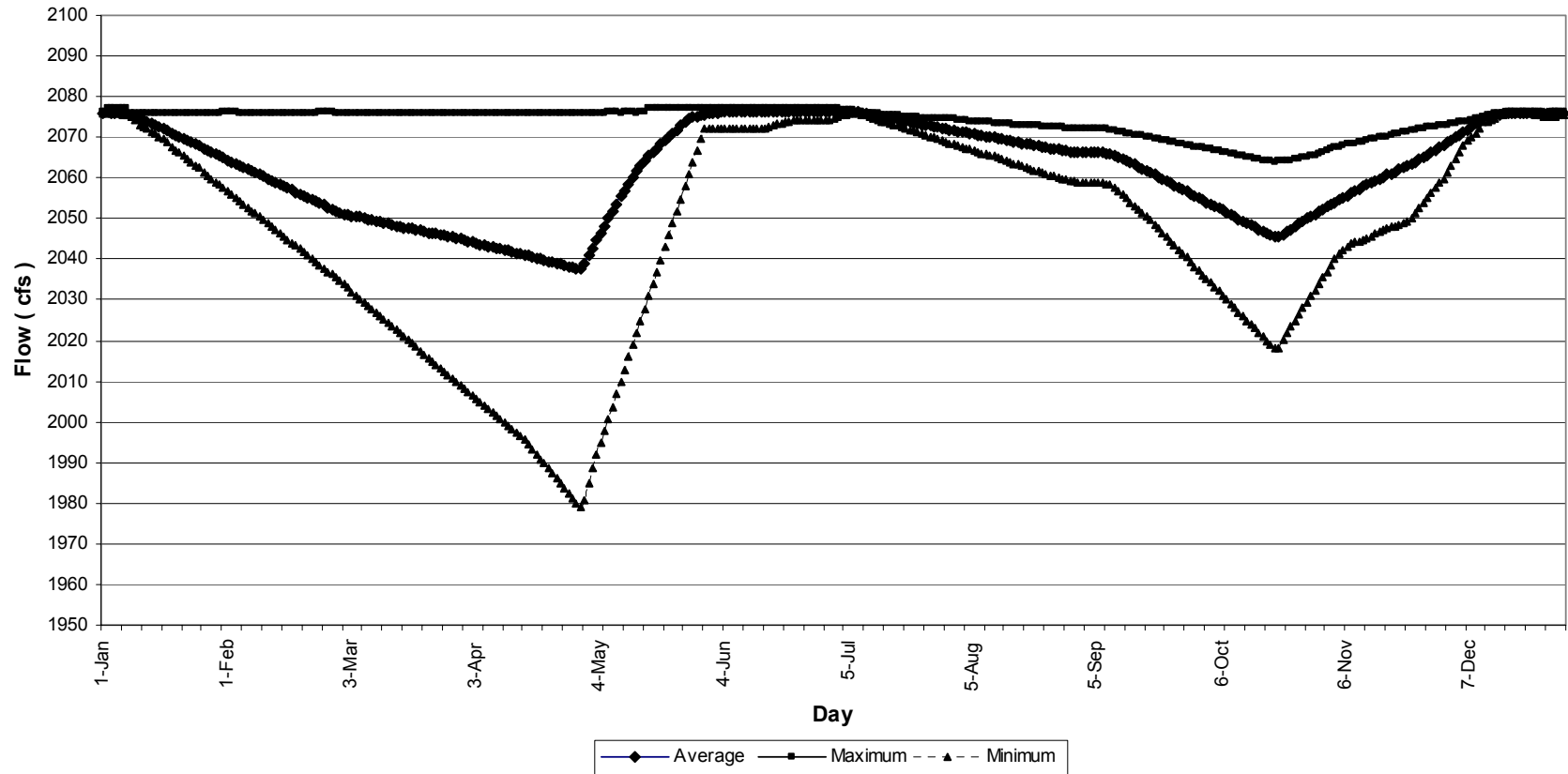
Brownlee Reservoir Proposed Water Surface Elevation - From 1970 to 1979



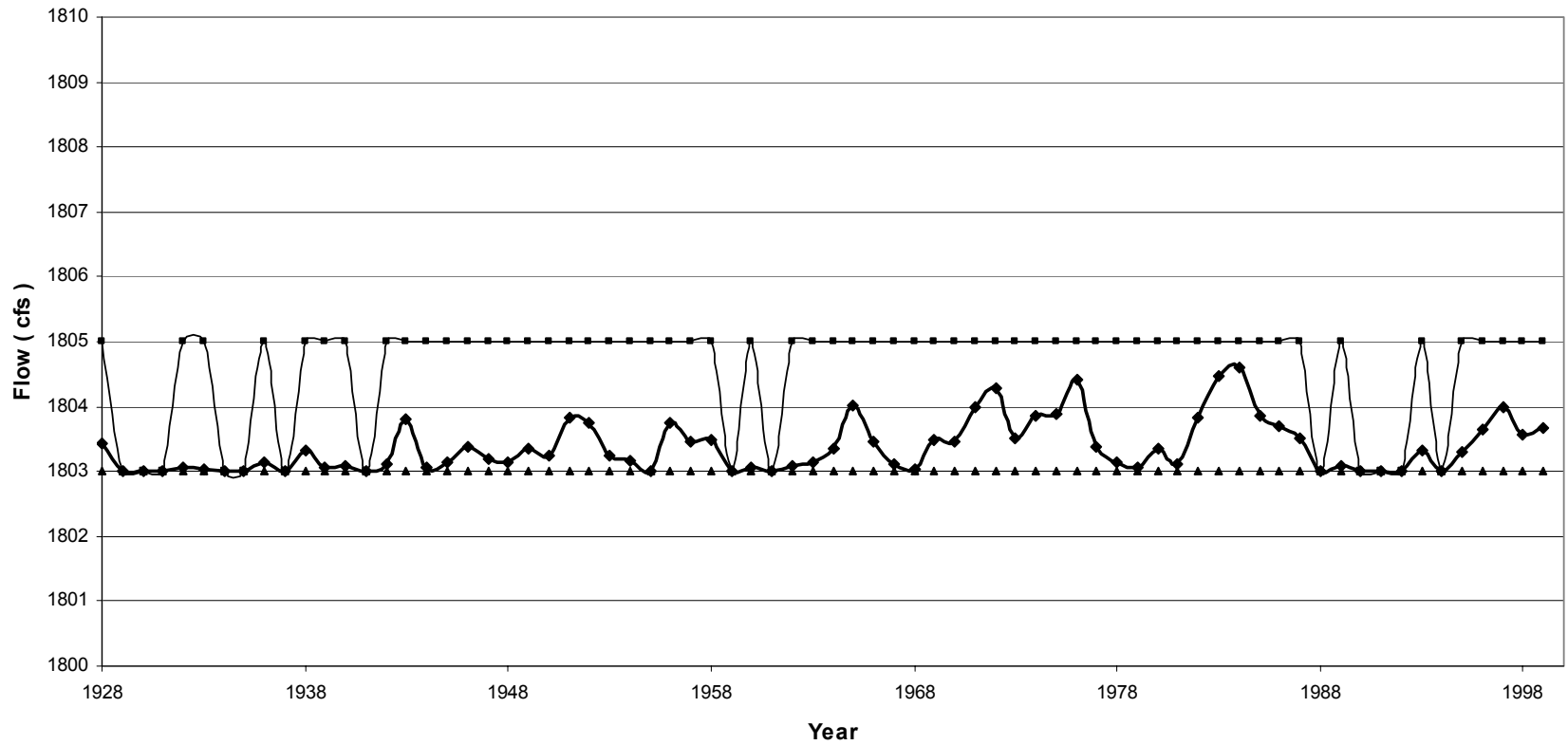
Brownlee Reservoir Proposed Water Surface Elevation - From 1980 to 1989



Brownlee Reservoir Proposed Water Surface Elevation - From 1990 to 1999

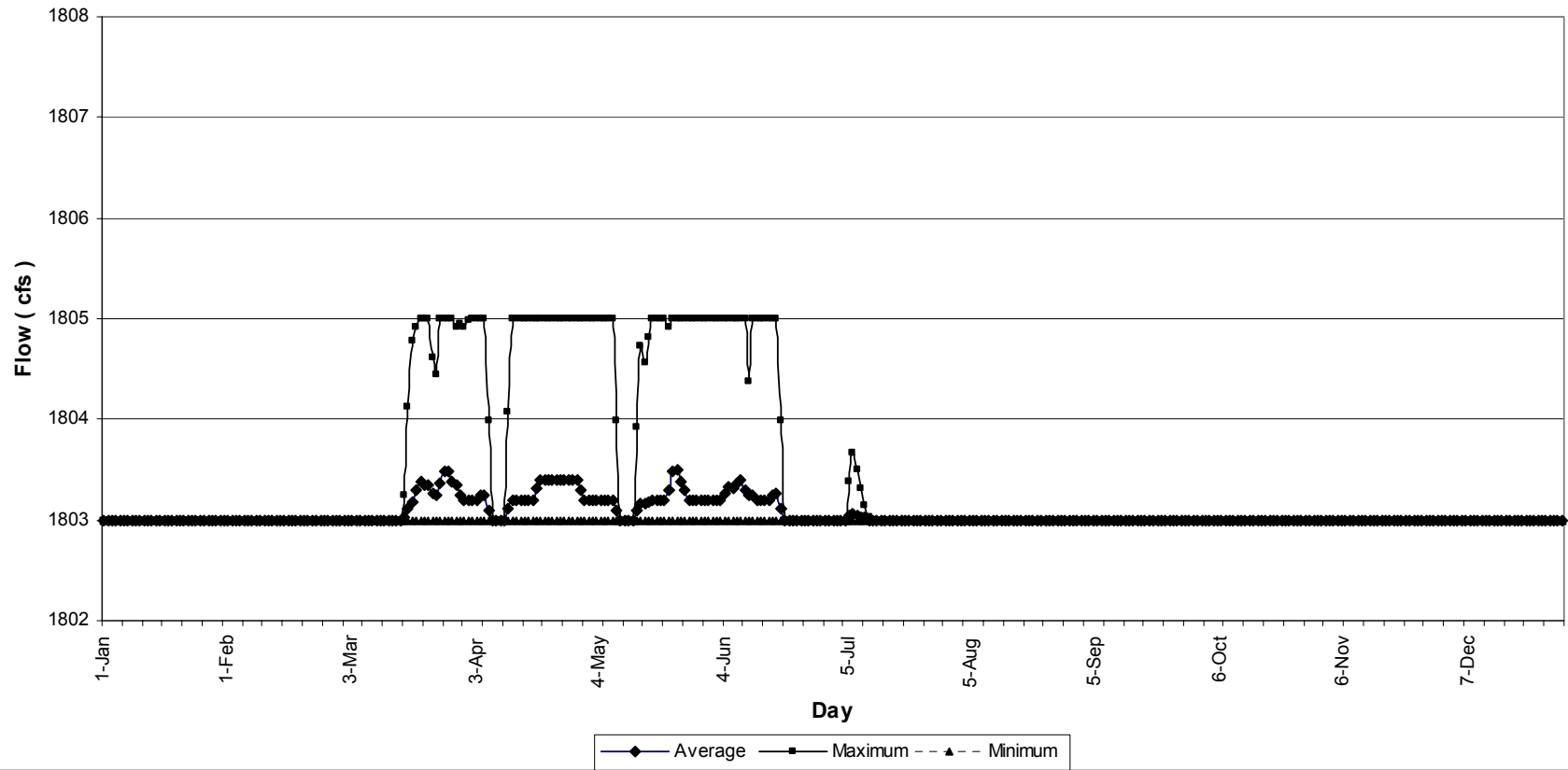


Proposed Water Surface Elevation at Oxbow Reservoir

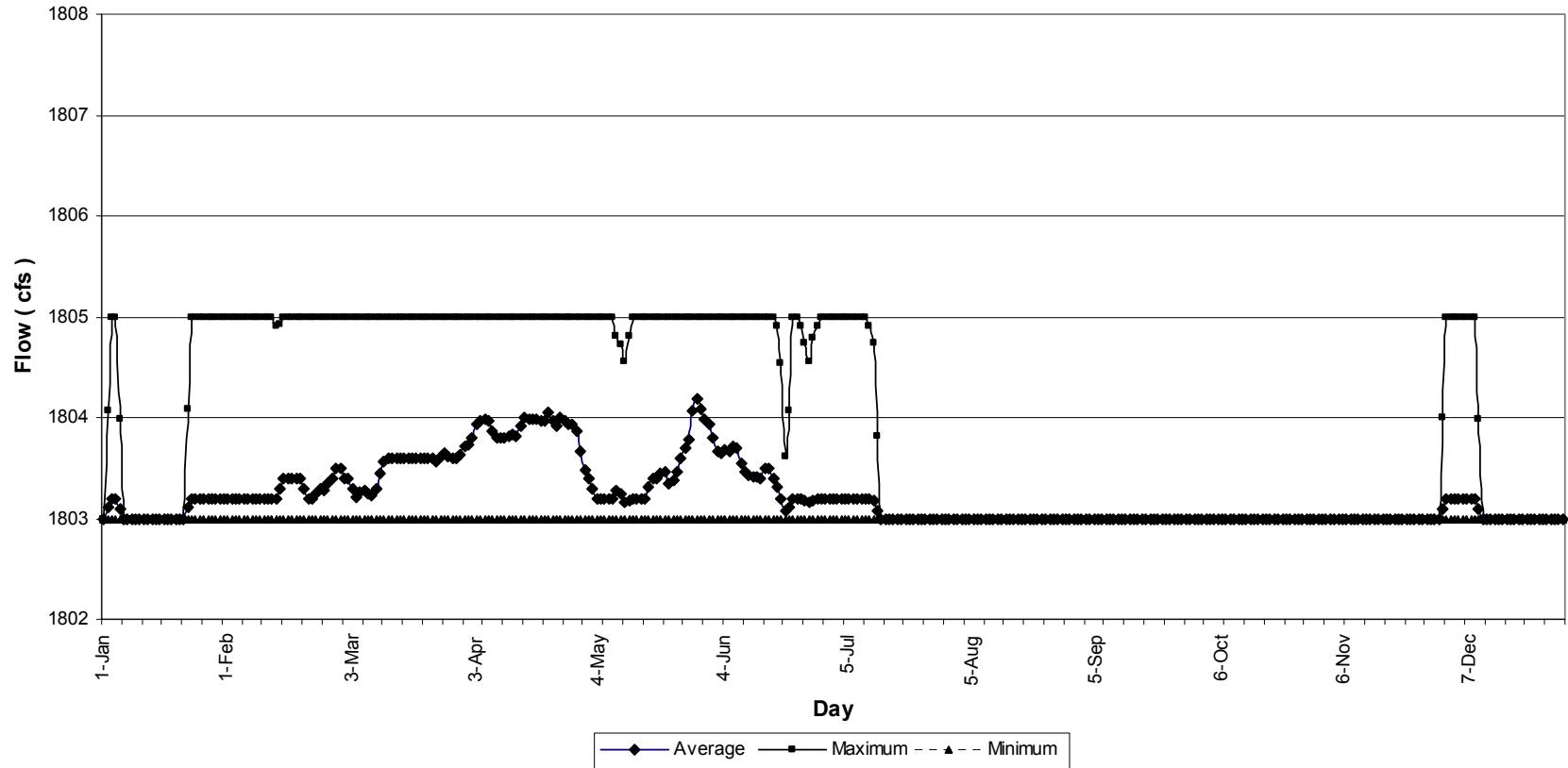


◆ Average Annual ■ Maximum Daily ▲ Minimum Daily

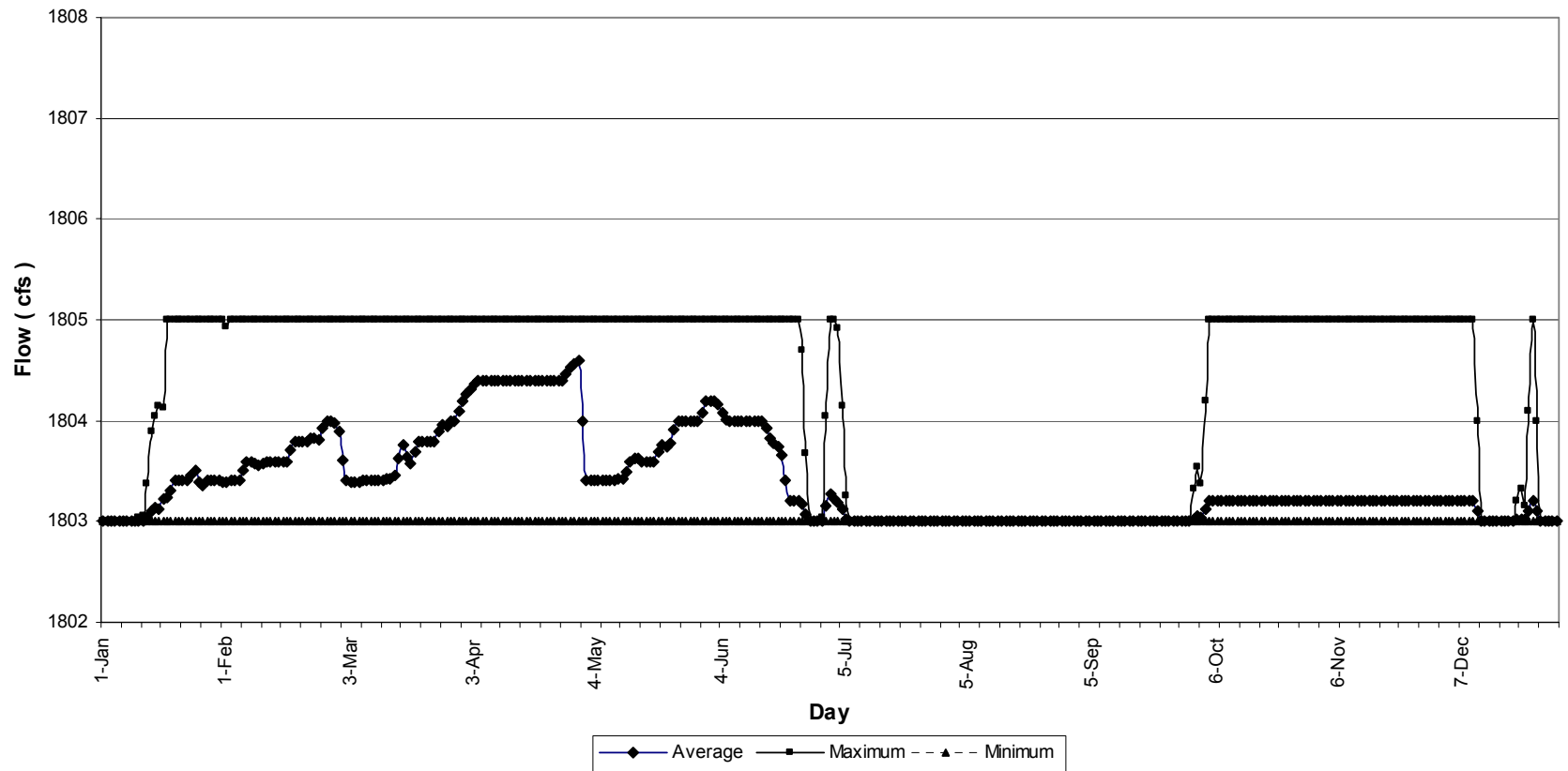
Oxbow Reservoir Proposed Water Surface Elevation - From 1930 to 1939



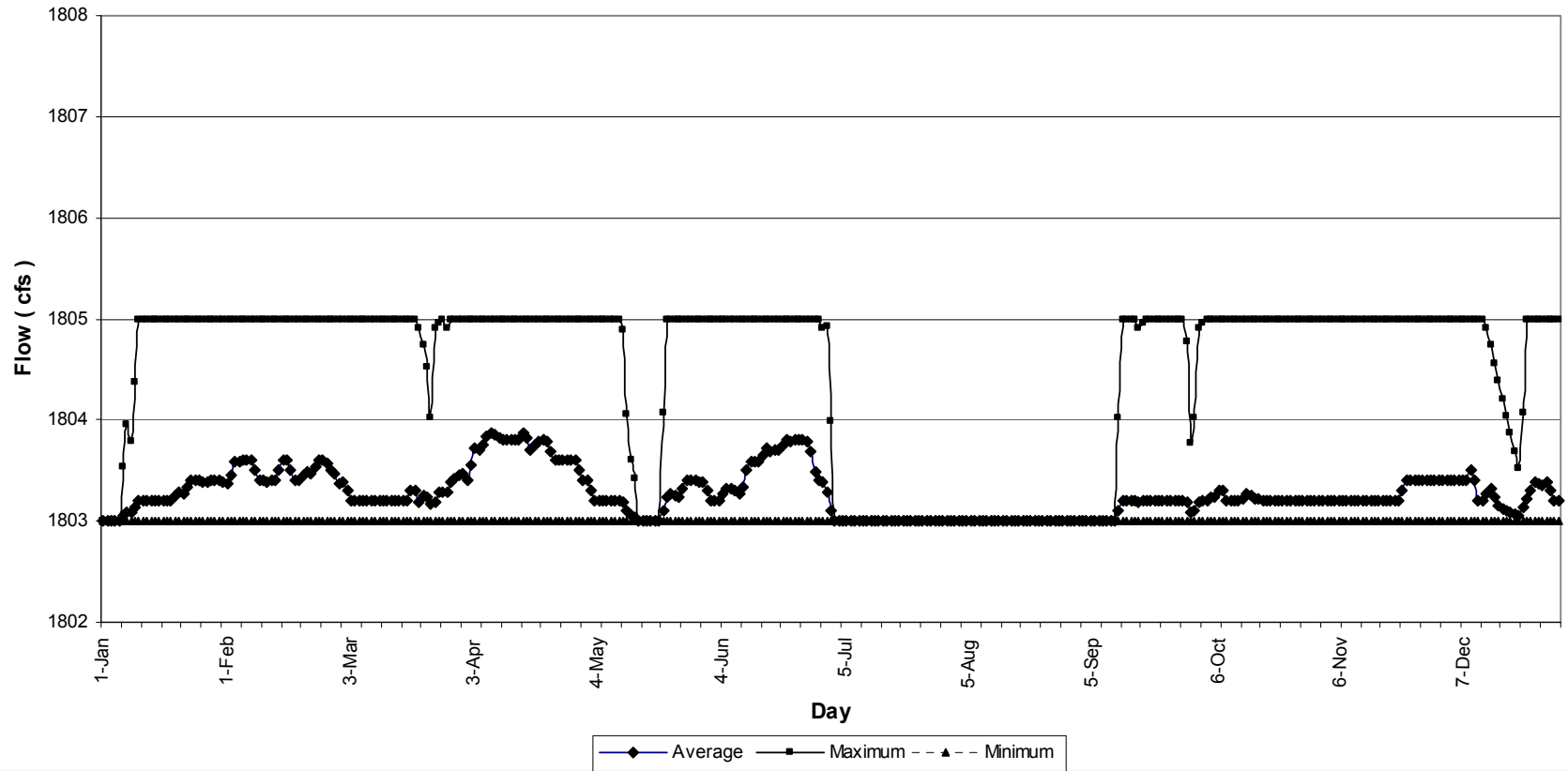
Oxbow Reservoir Proposed Water Surface Elevation - From 1940 to 1949



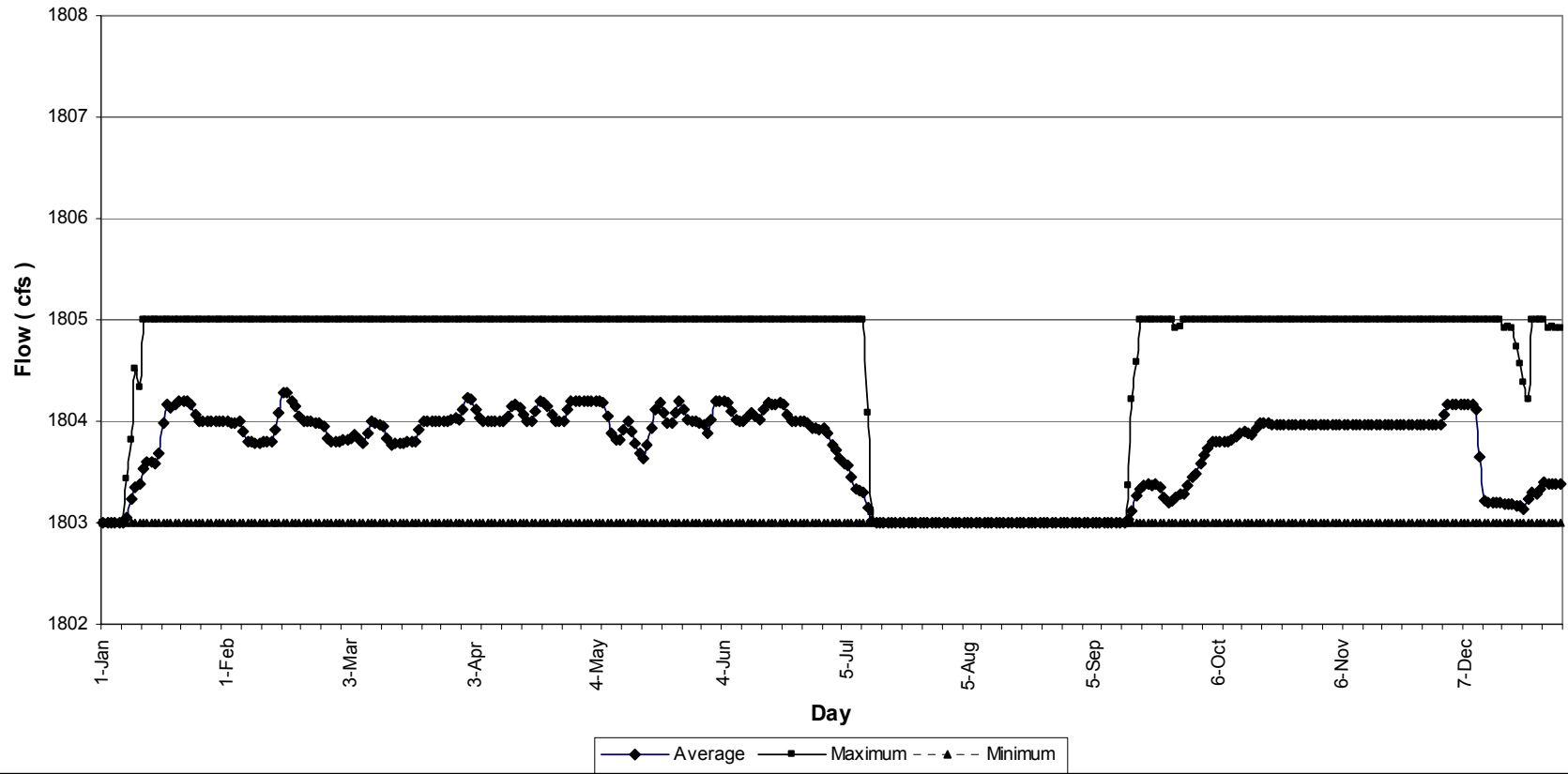
Oxbow Reservoir Proposed Water Surface Elevation - From 1950 to 1959



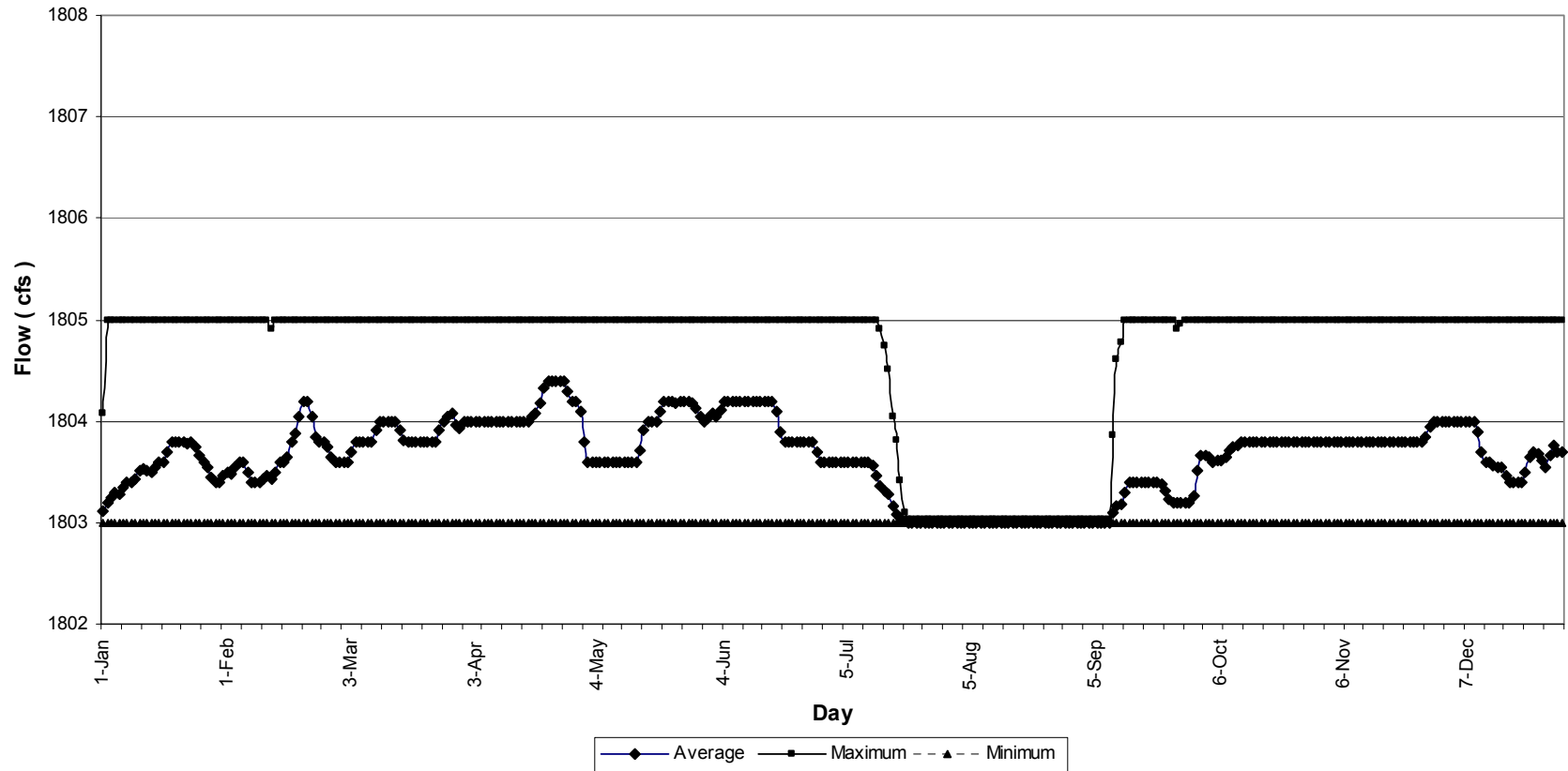
Oxbow Reservoir Proposed Water Surface Elevation - From 1960 to 1969



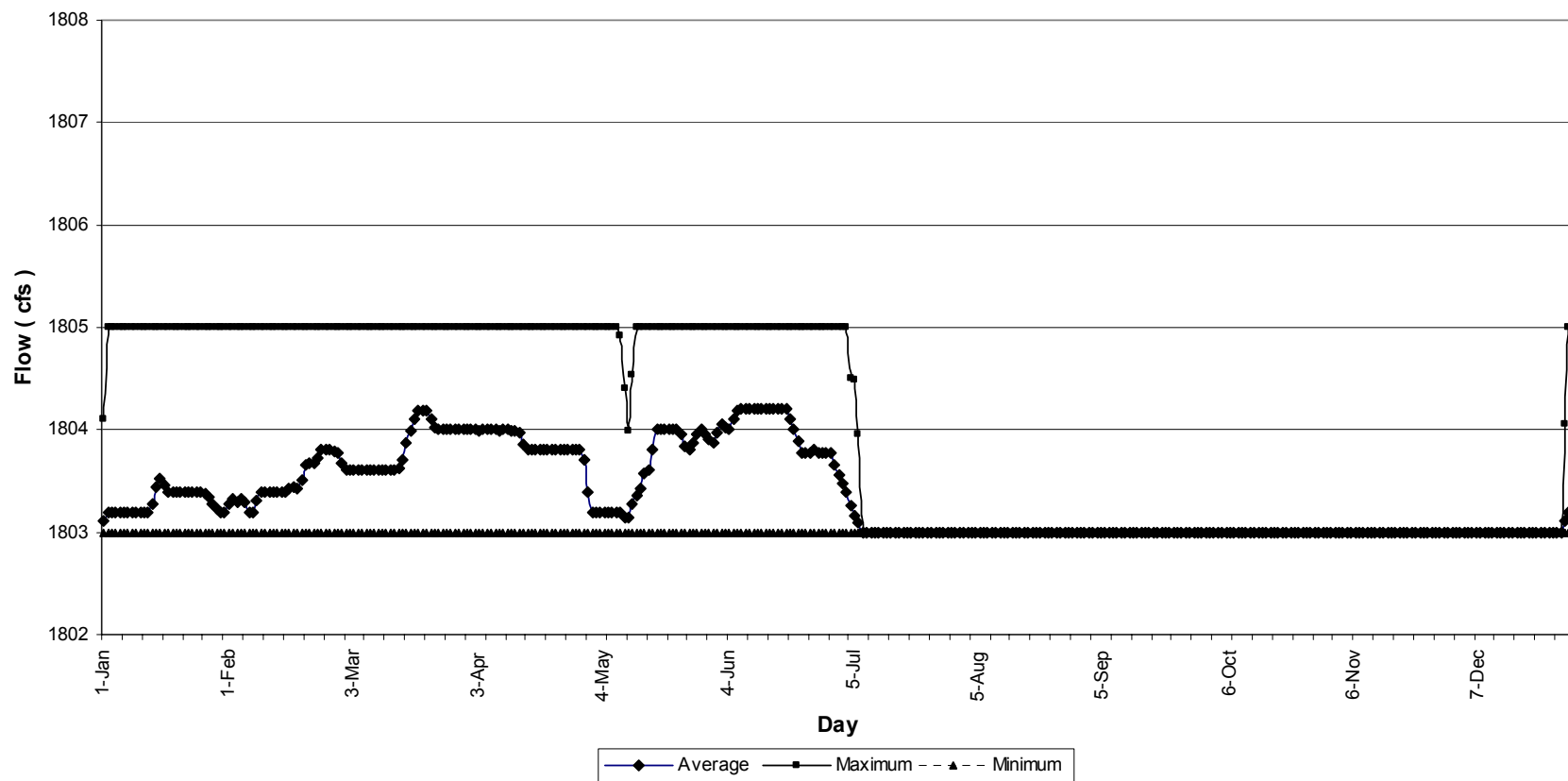
Oxbow Reservoir Proposed Water Surface Elevation - From 1970 to 1979



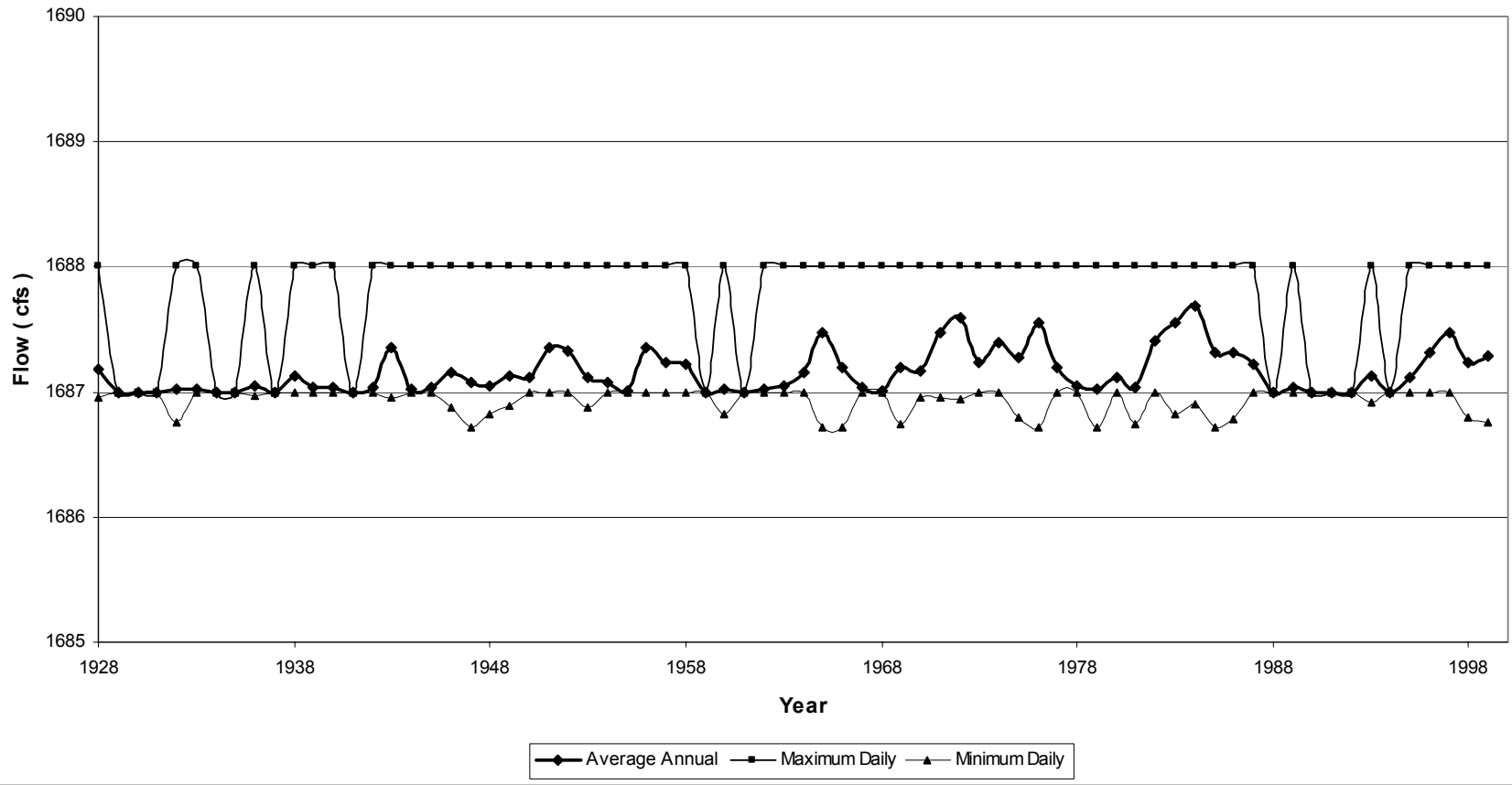
Oxbow Reservoir Proposed Water Surface Elevation - From 1980 to 1989



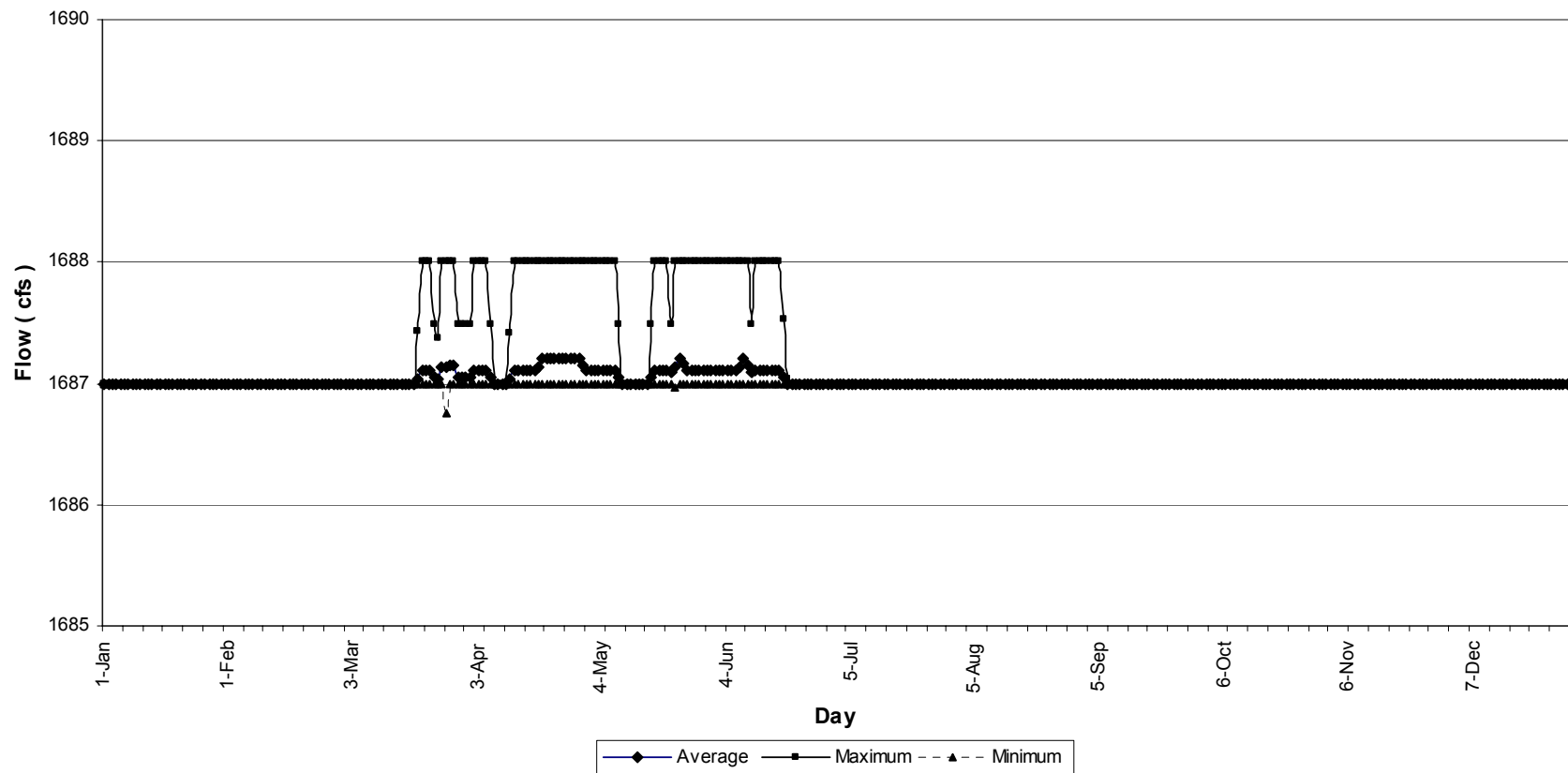
Oxbow Reservoir Proposed Water Surface Elevation - From 1990 to 1999



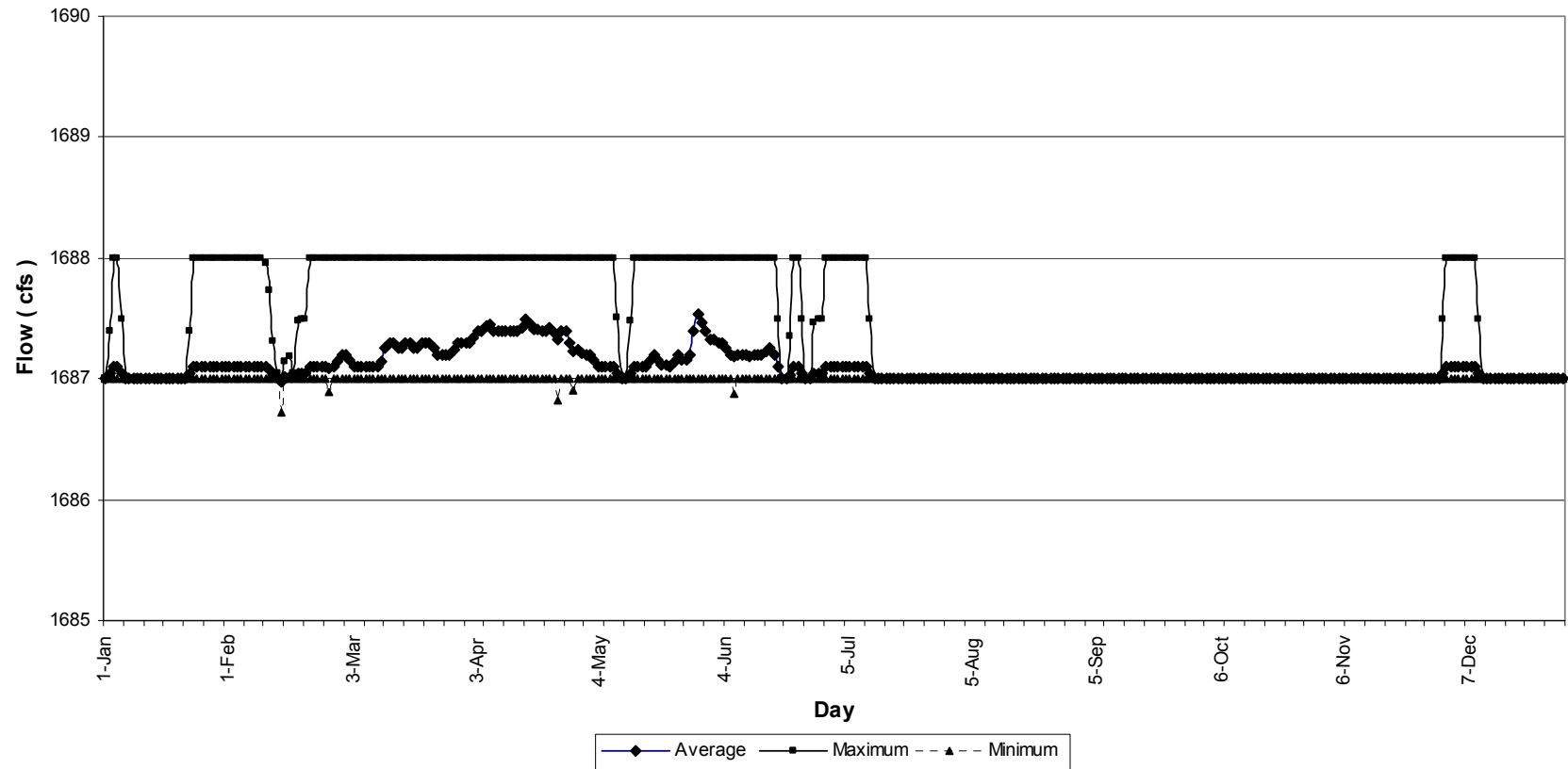
Proposed Water Surface Elevation at Hells Canyon Reservoir



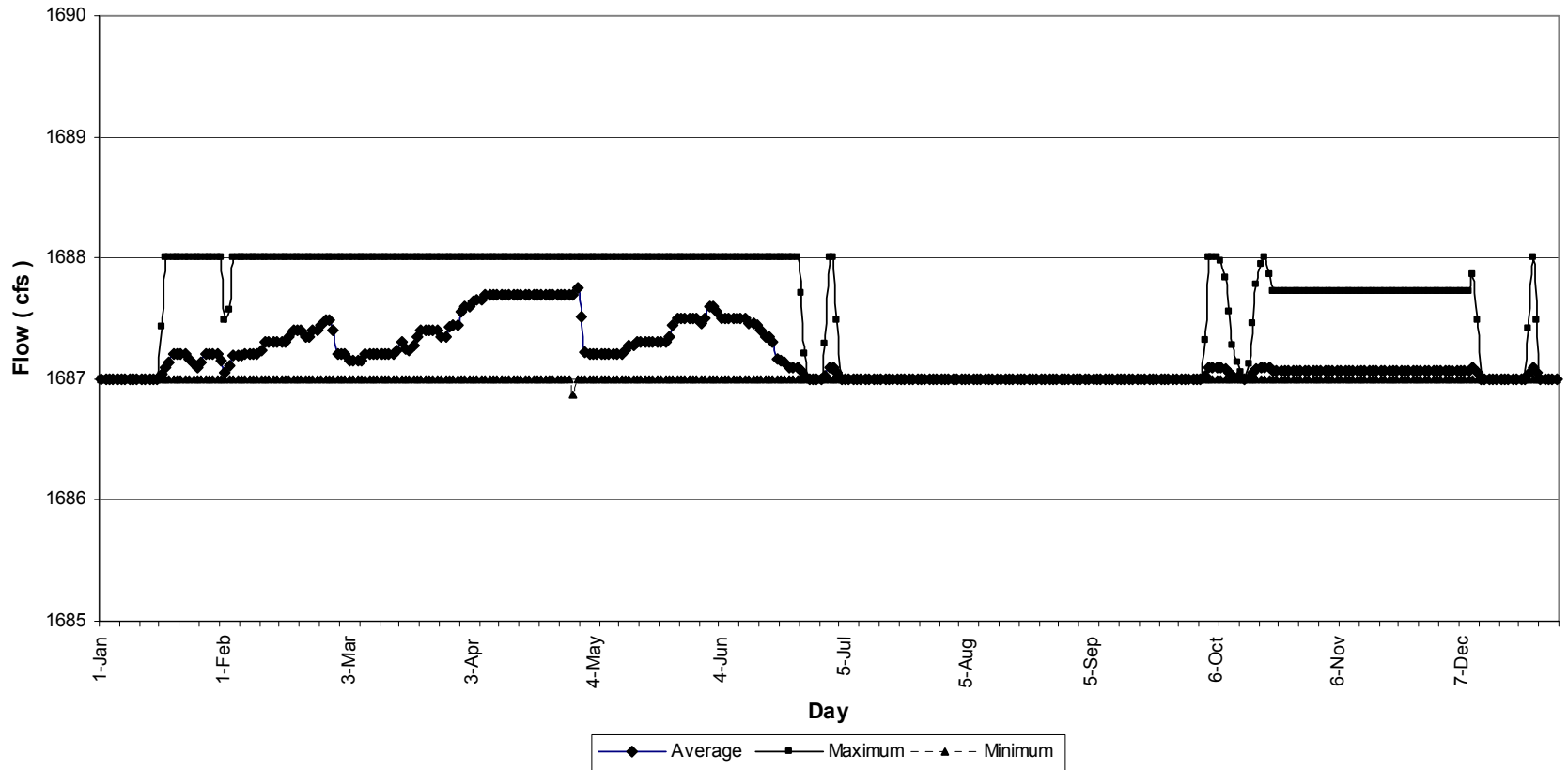
Hells Canyon Reservoir Proposed Water Surface Elevation - From 1930 to 1939



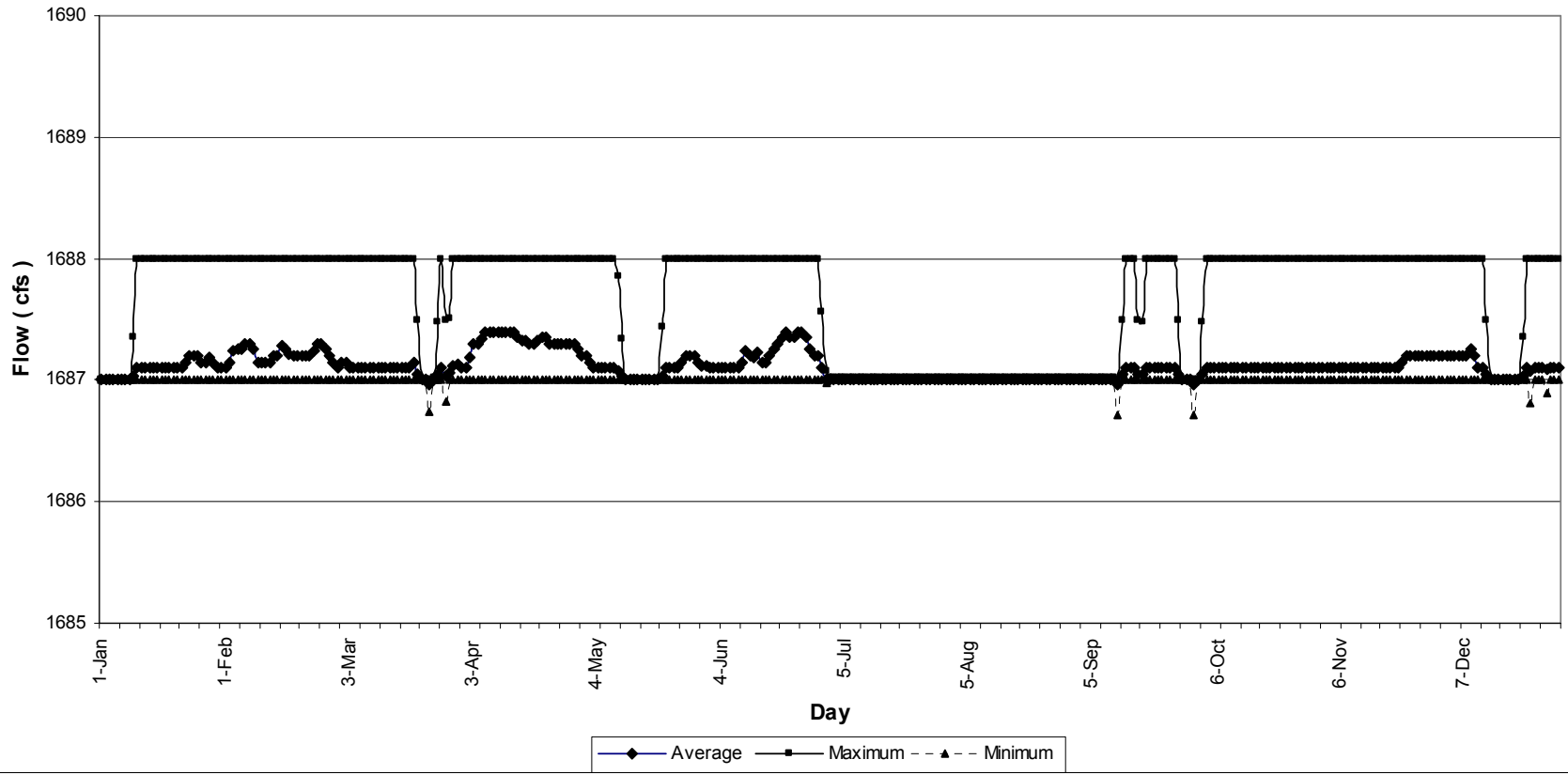
Hells Canyon Reservoir Proposed Water Surface Elevation - From 1940 to 1949



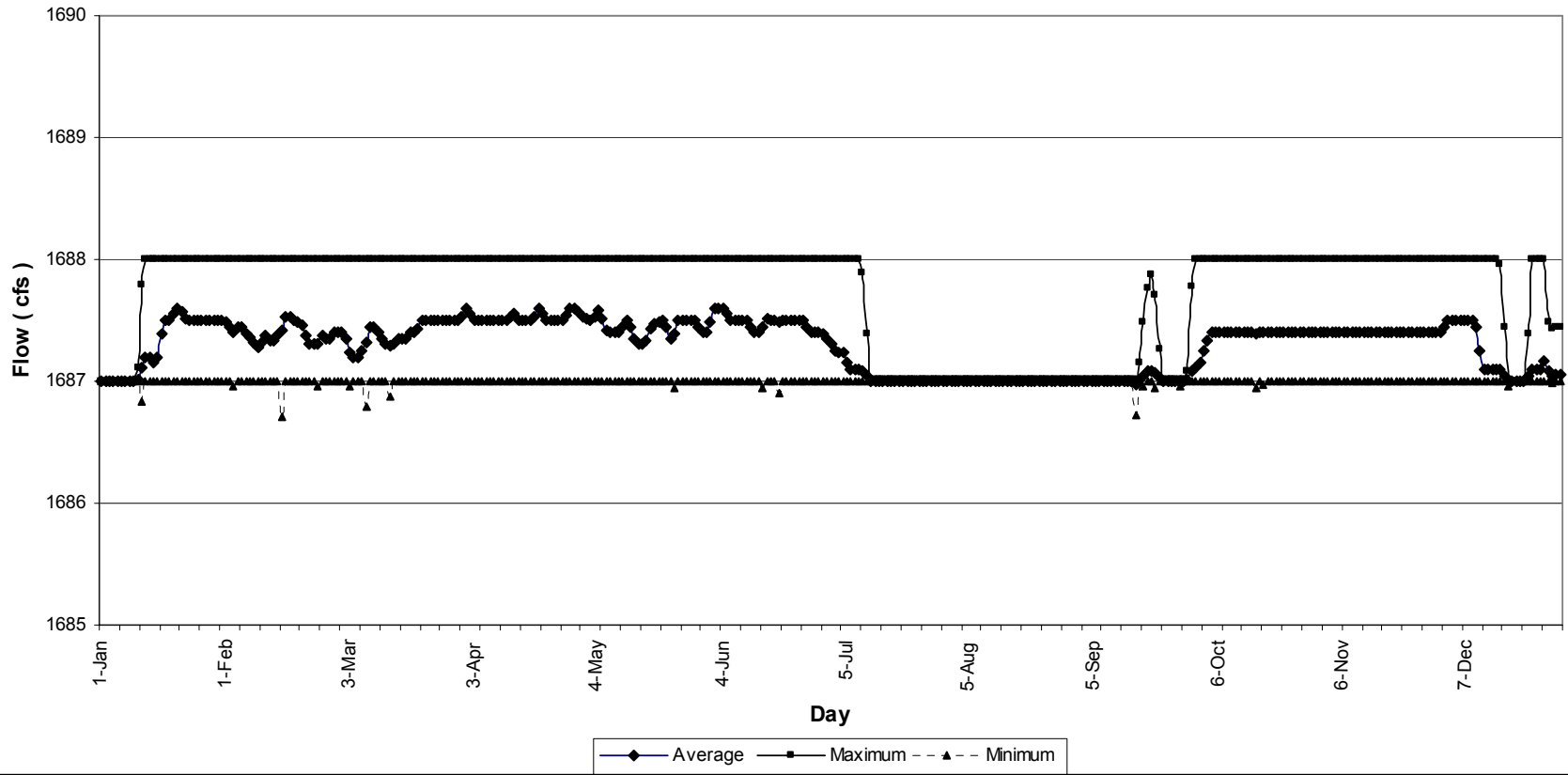
Hells Canyon Reservoir Proposed Water Surface Elevation - From 1950 to 1959



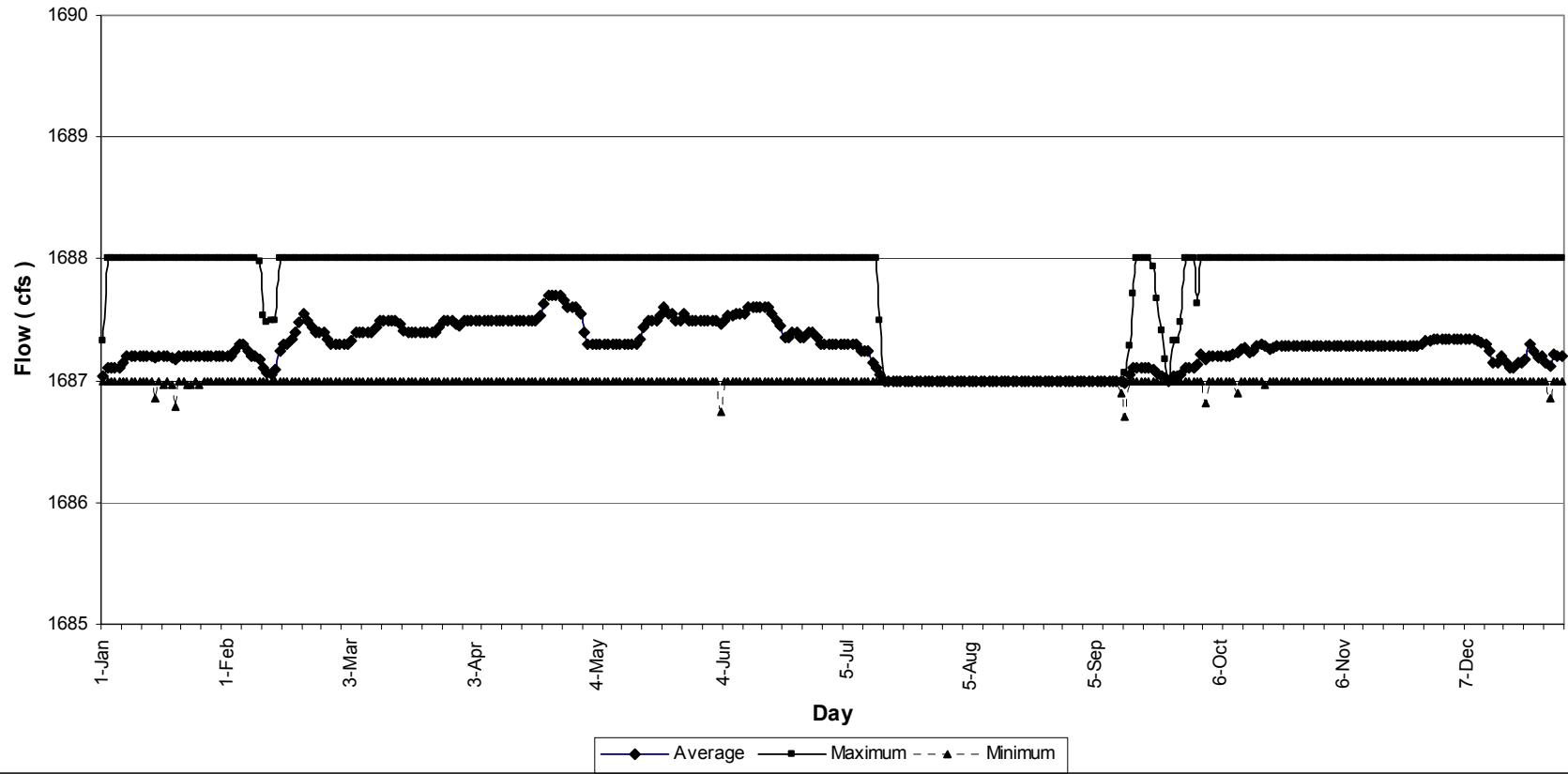
Hells Canyon Reservoir Proposed Water Surface Elevation - From 1960 to 1969



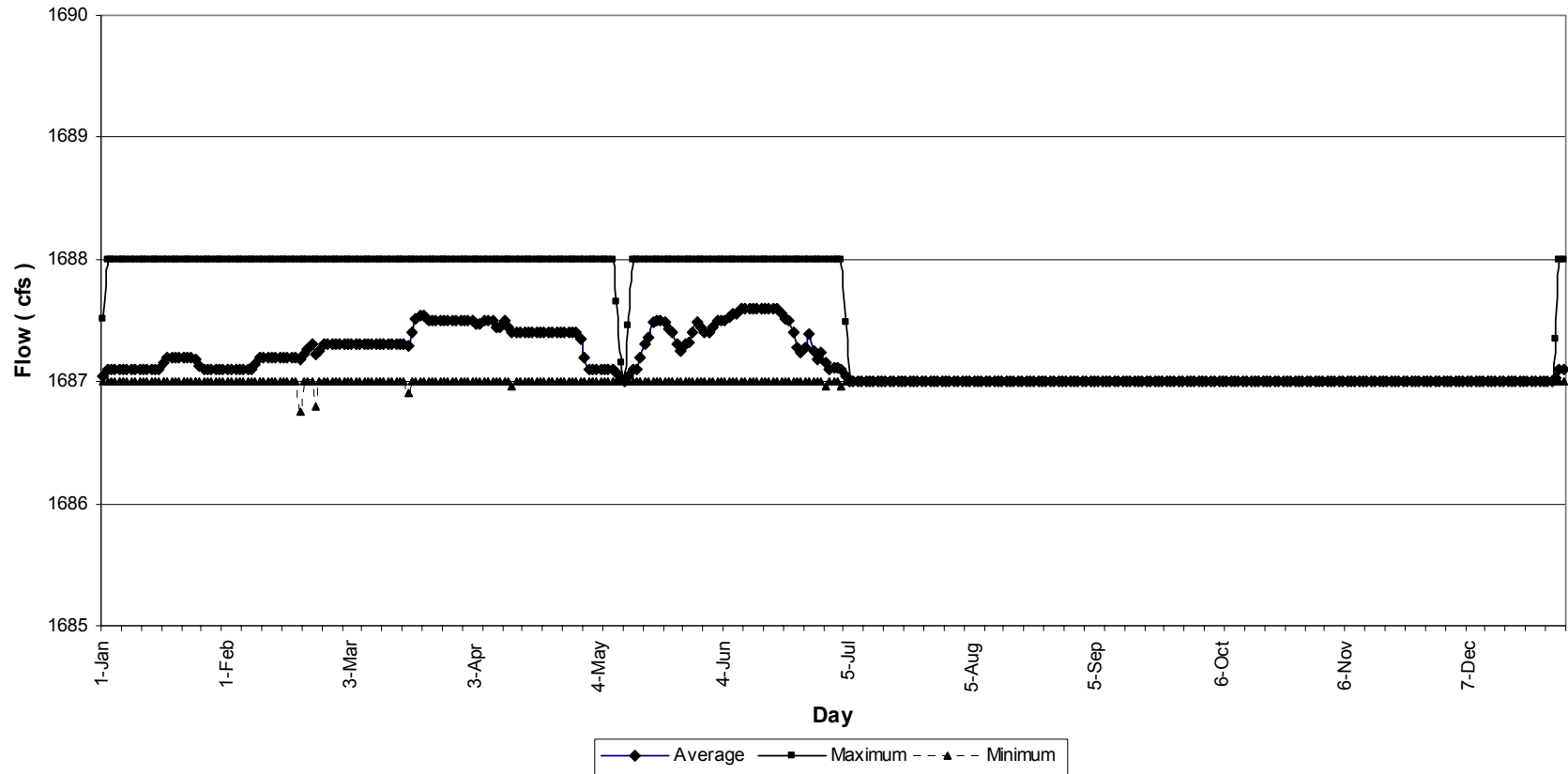
Hells Canyon Reservoir Proposed Water Surface Elevation - From 1970 to 1979



Hells Canyon Reservoir Proposed Water Surface Elevation - From 1980 to 1989



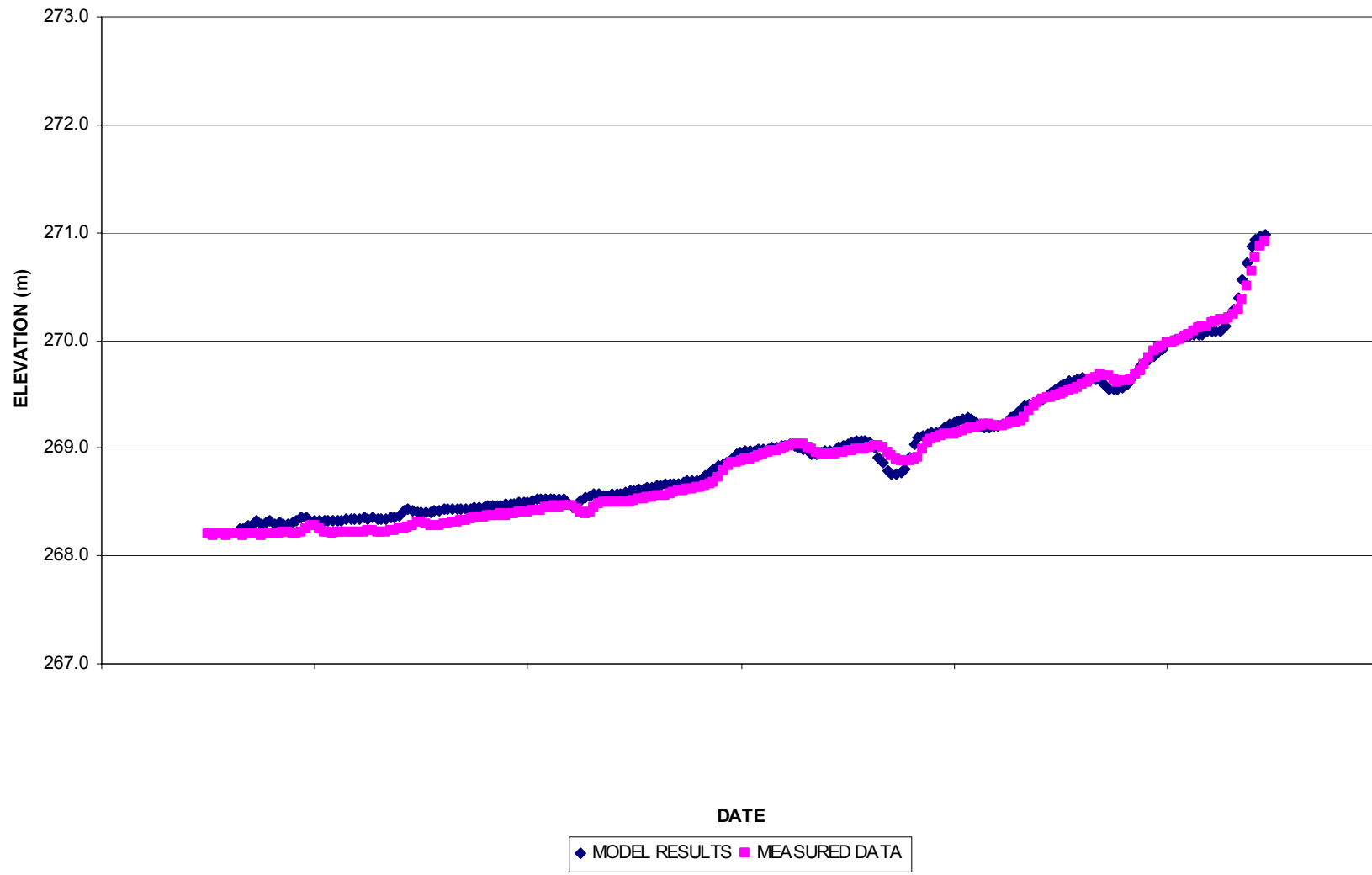
Hells Canyon Reservoir Proposed Water Surface Elevation - From 1990 to 1999



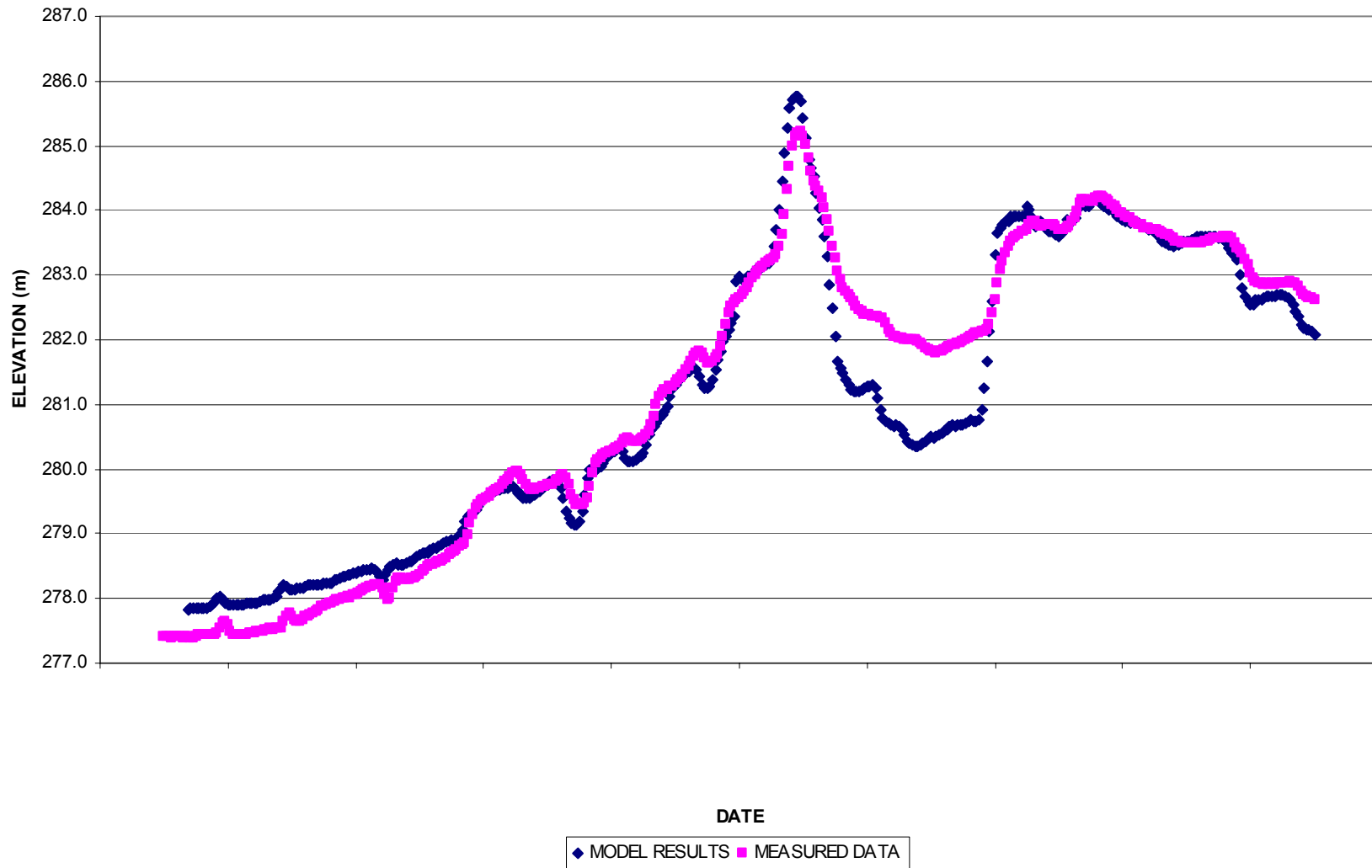
Appendix 3.6. Snake River Hydraulic Model Calibration

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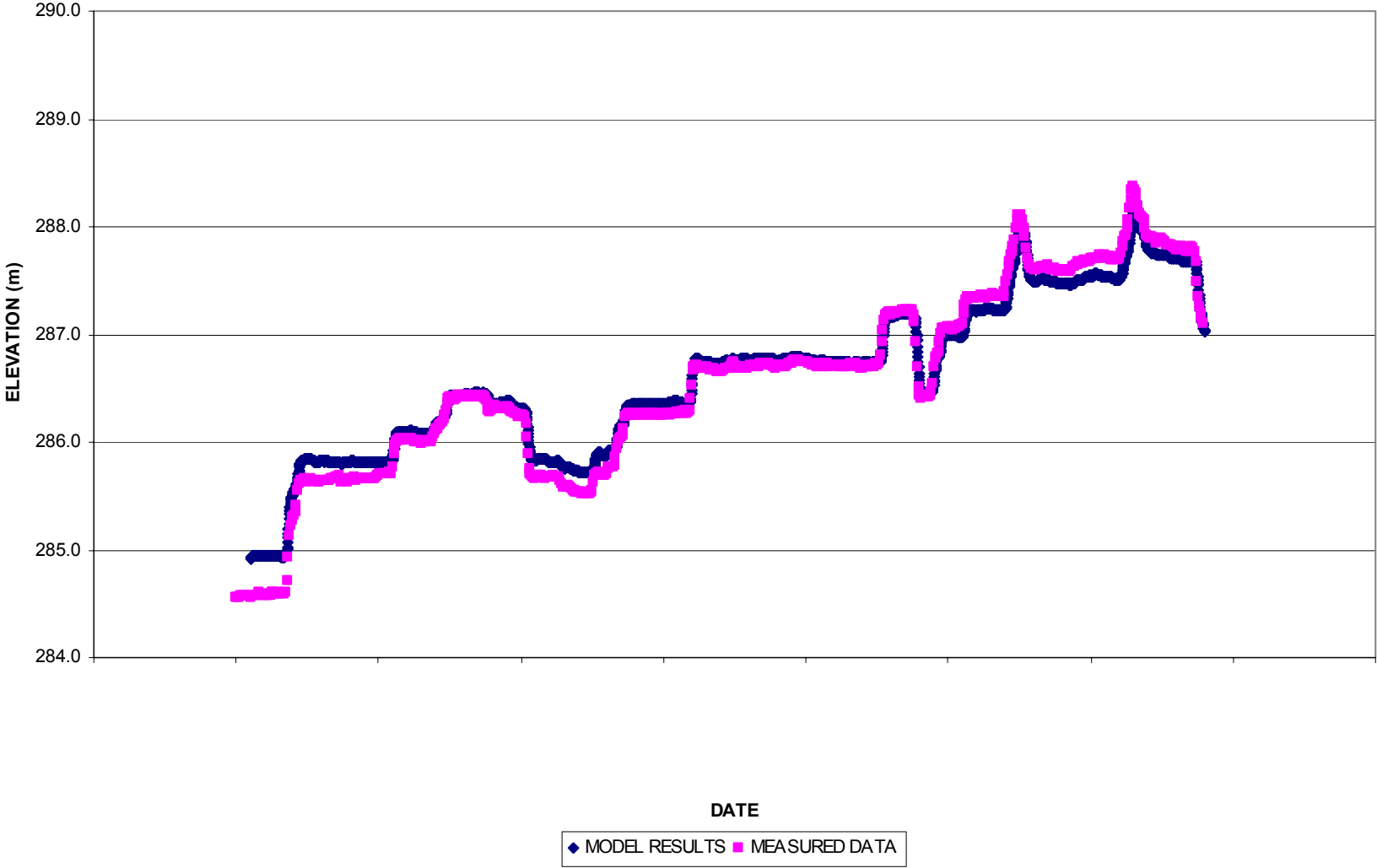
HYDRAULIC MODEL CALIBRATION - COUGAR BAR PT CHAINAGE 109259



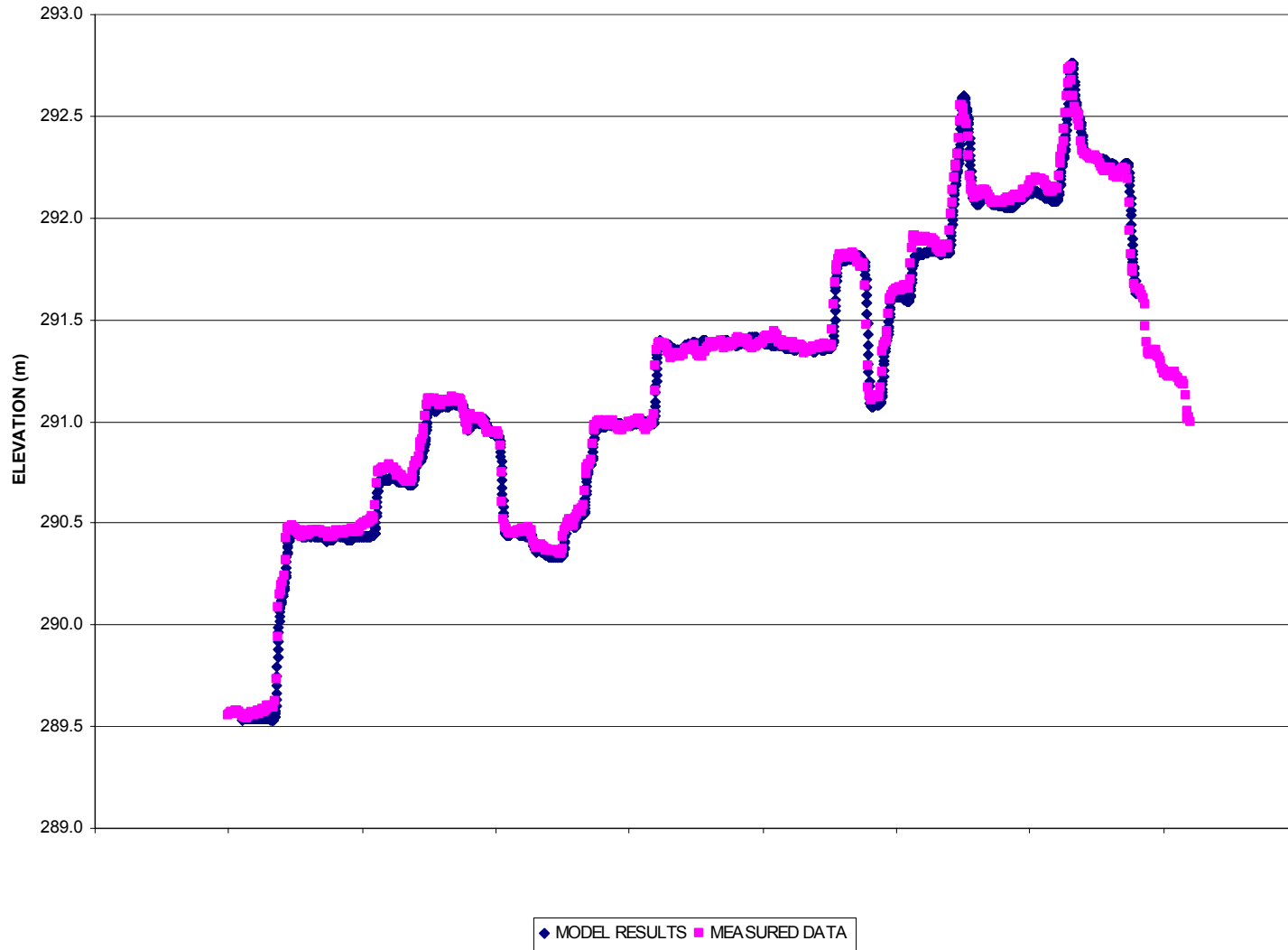
**HYDRAULIC MODEL CALIBRATION - BELOW SALMON PT
CHAINAGE 97031**



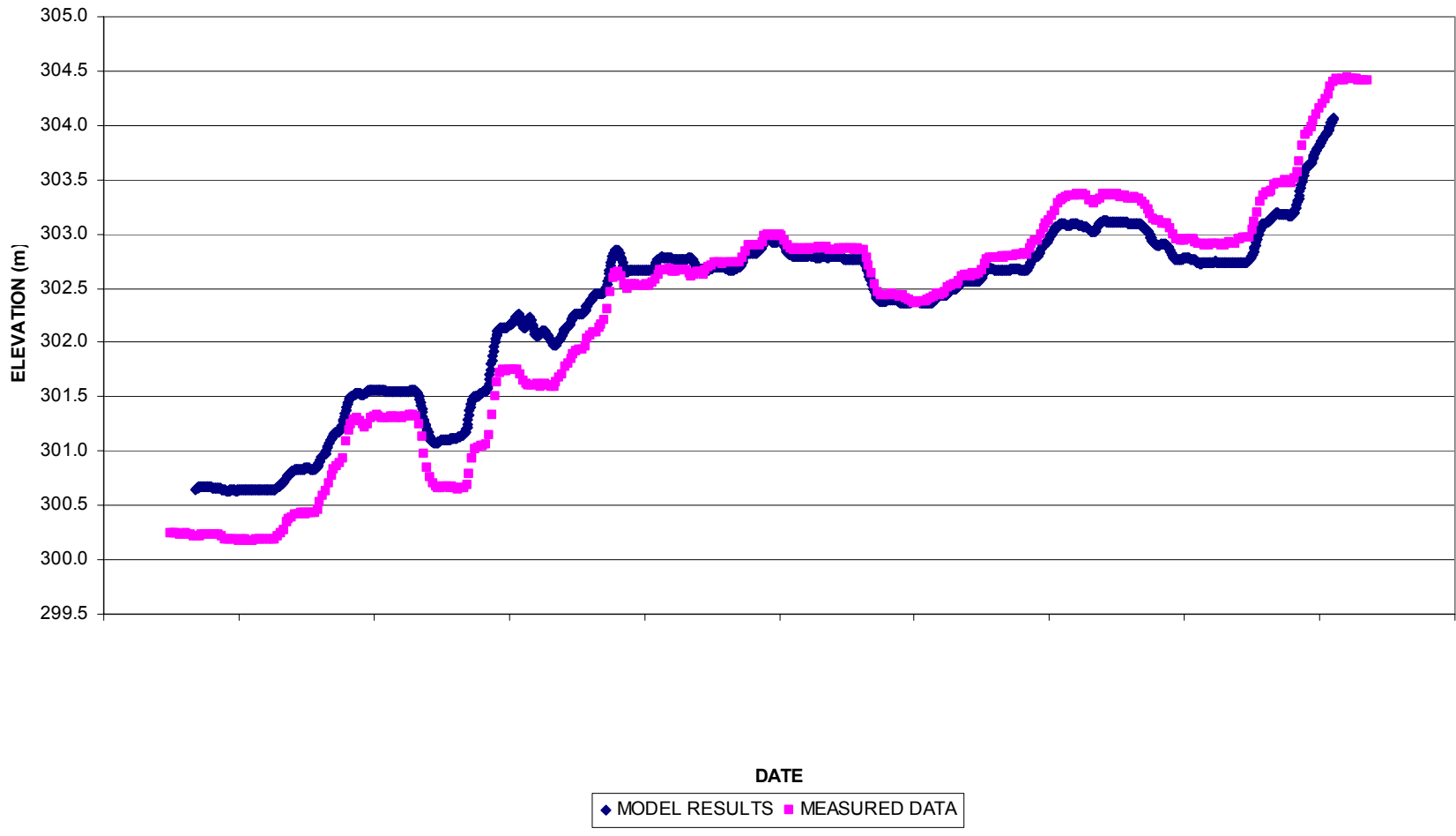
**HYDRAULIC MODEL CALIBRATION - EURIKA BAR PT
CHAINAGE 91625**



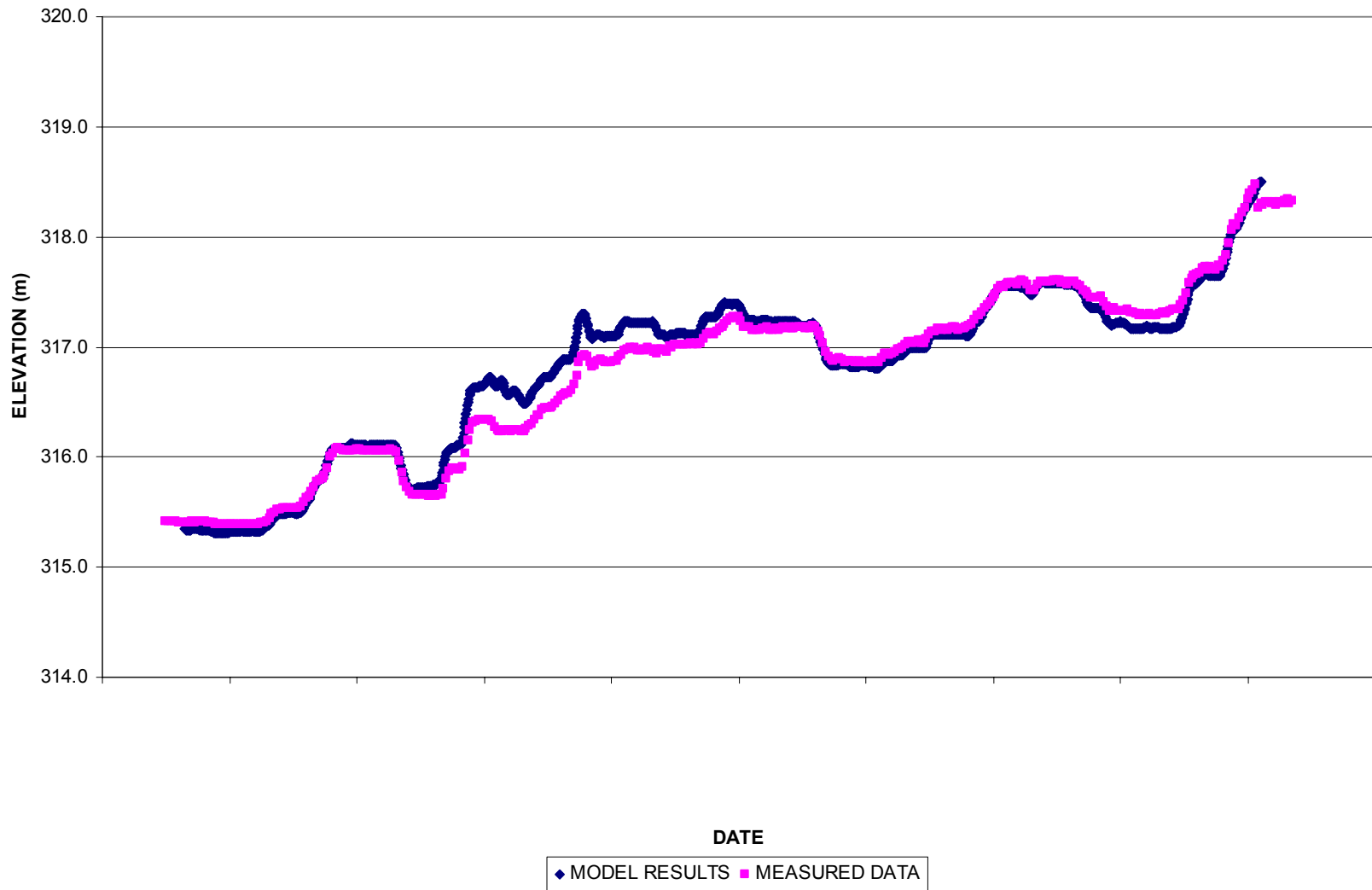
HYDRAULIC MODEL CALIBRATION - CHINA BAR PT
CHAINAGE 88986



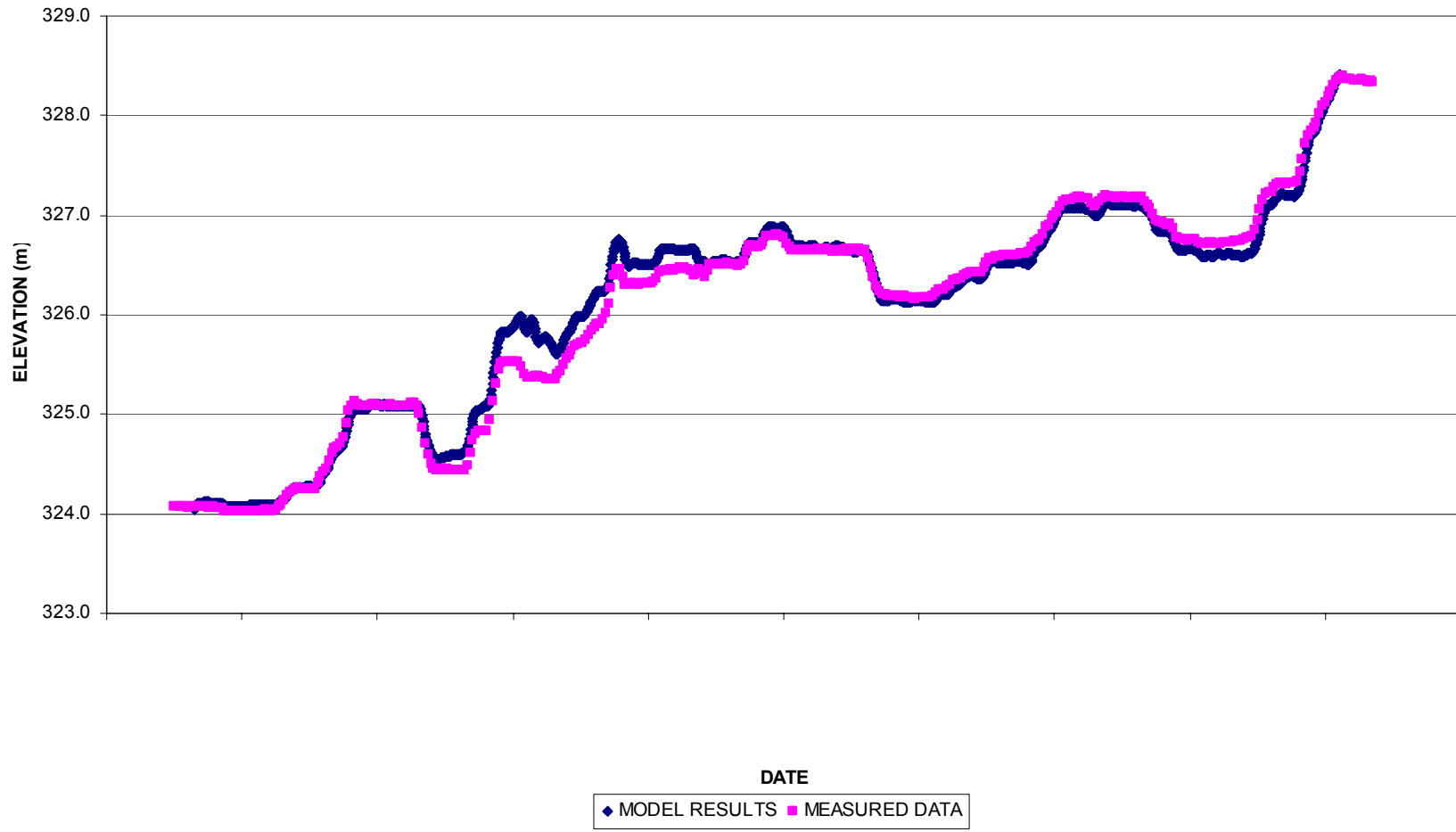
HYDRAULIC MODEL CALIBRATION - DUG BAR PT
CHAINAGE 83081



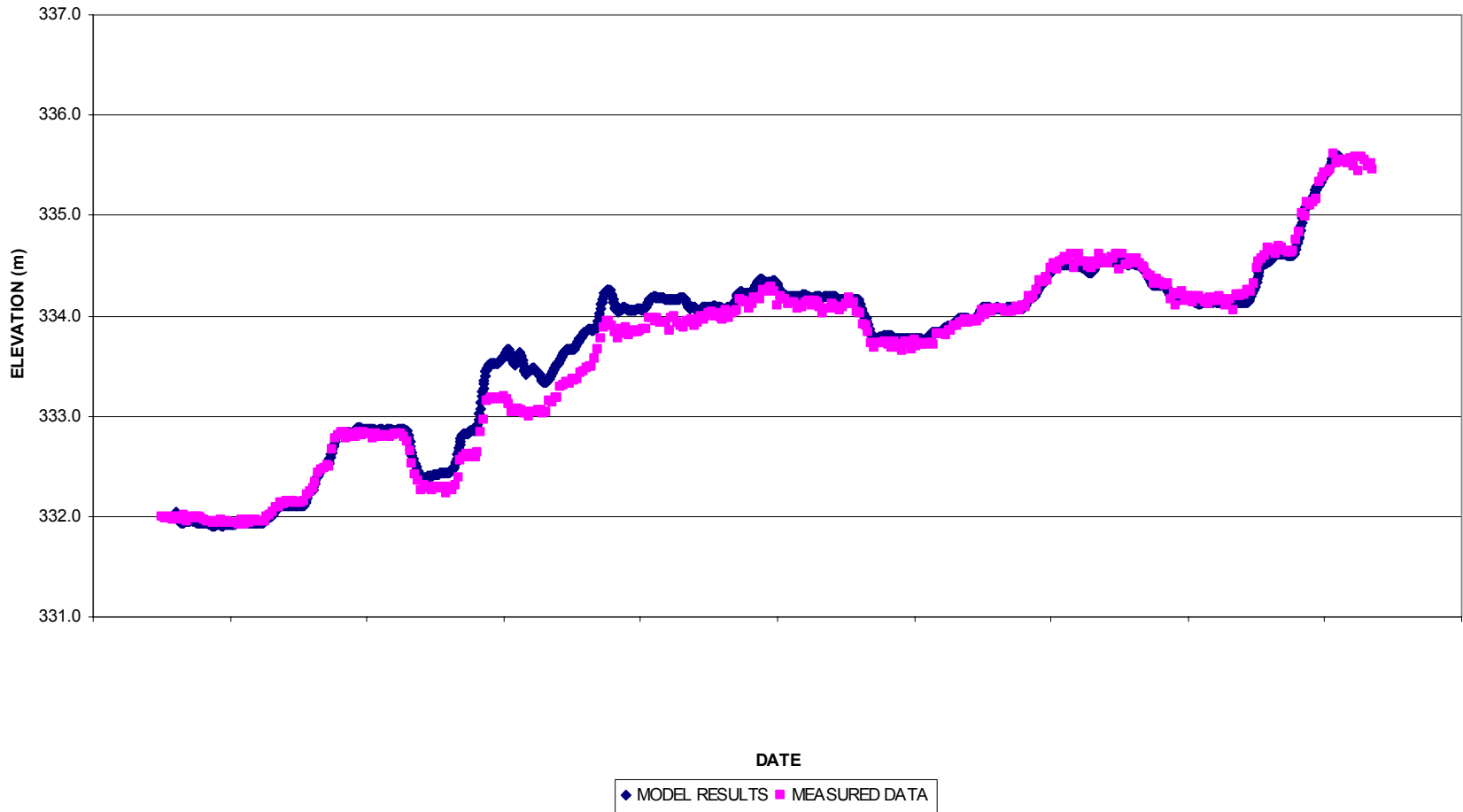
HYDRAULIC MODEL CALIBRATION - FLYING H PT
CHAINAGE 73057



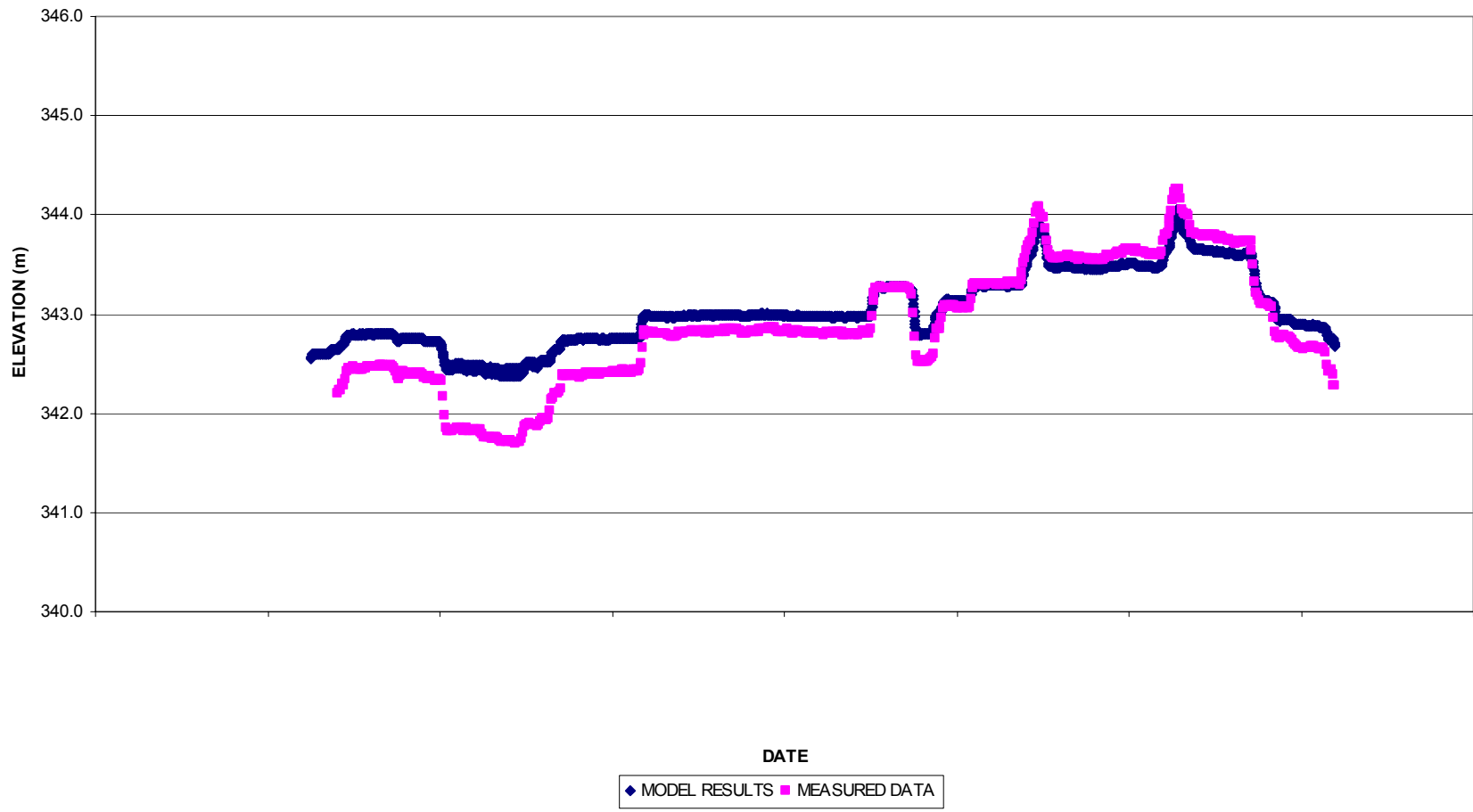
**HYDRAULIC MODEL CALIBRATION - HIGH RANGE PT
CHAINAGE 65977**



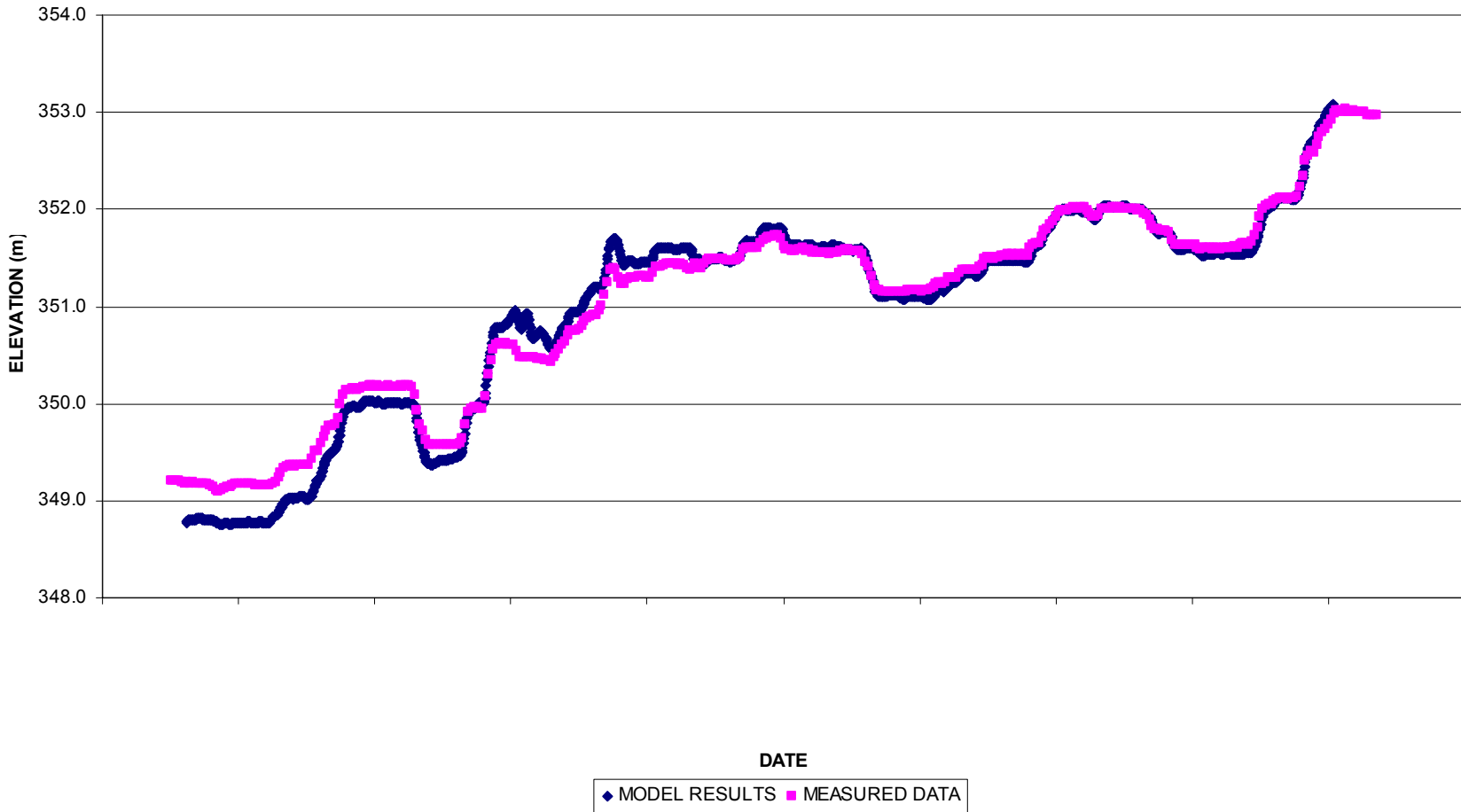
HYDRAULIC MODEL CALIBRATION - UPPER CAMP CREEK PT
CHAINAGE 60828



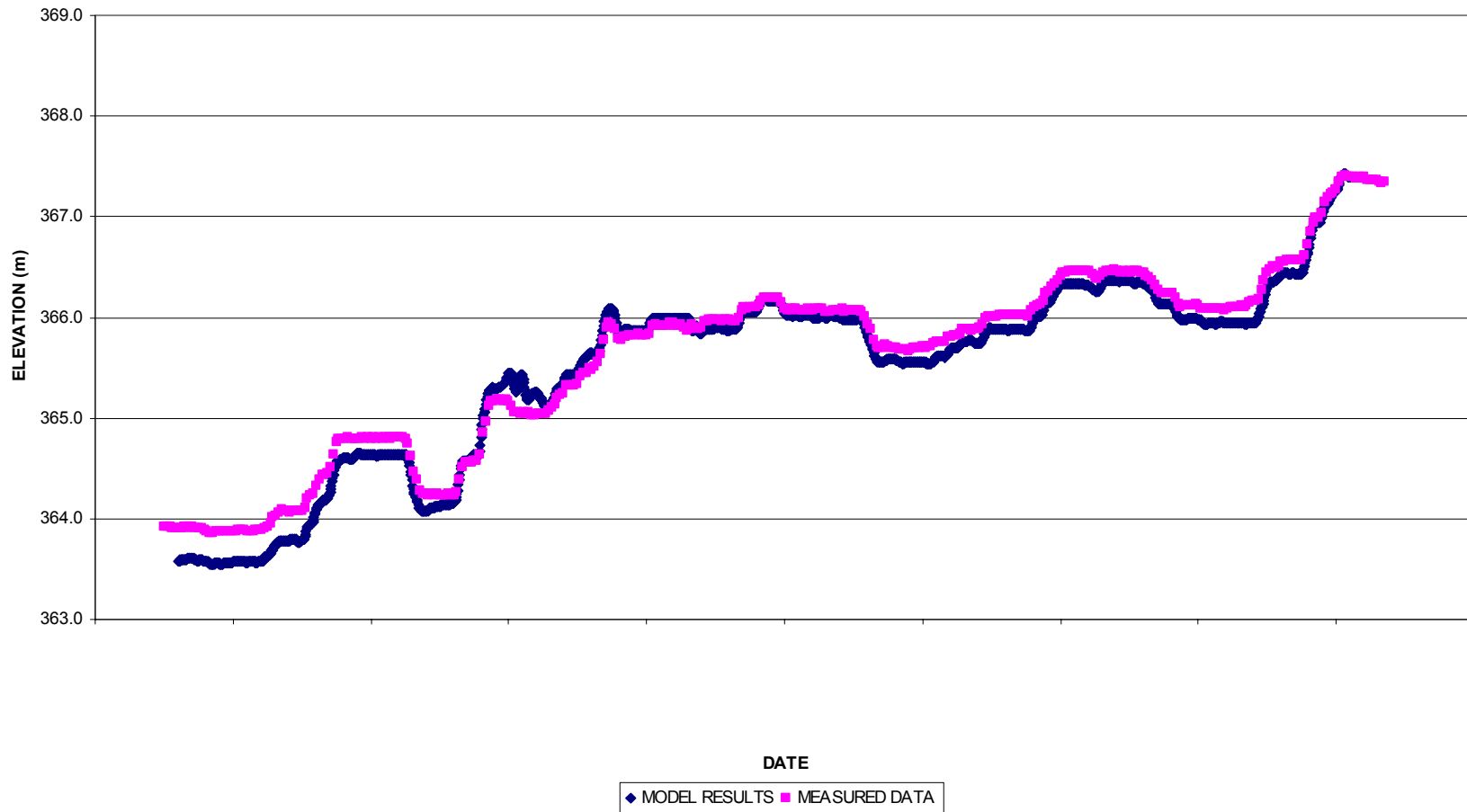
HYDRAULIC MODEL CALIBRATION - PLEASANT VALLEY PT CHAINAGE 54199



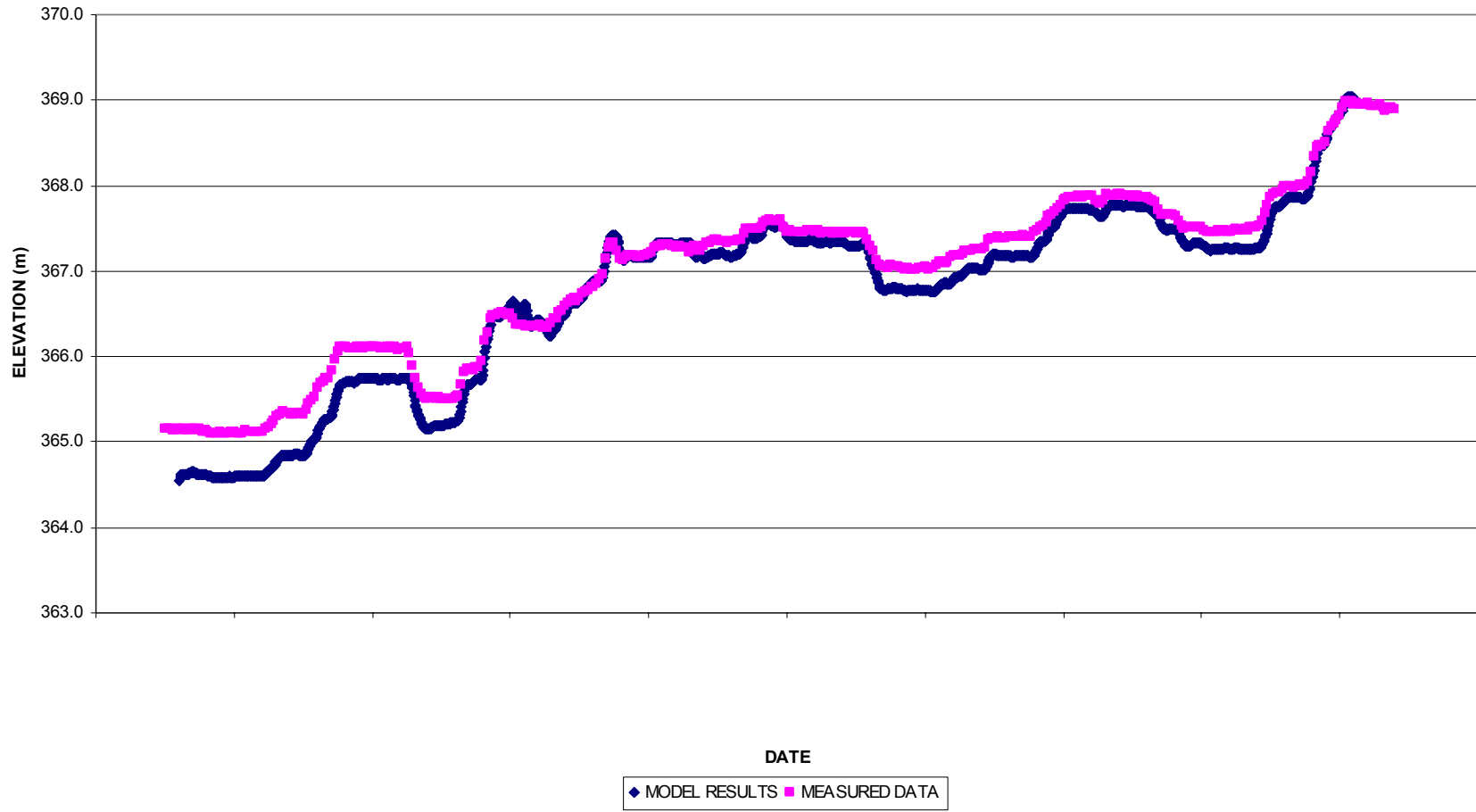
**HYDRAULIC MODEL CALIBRATION - FISH TRAP BAR PT
CHAINAGE 49951**



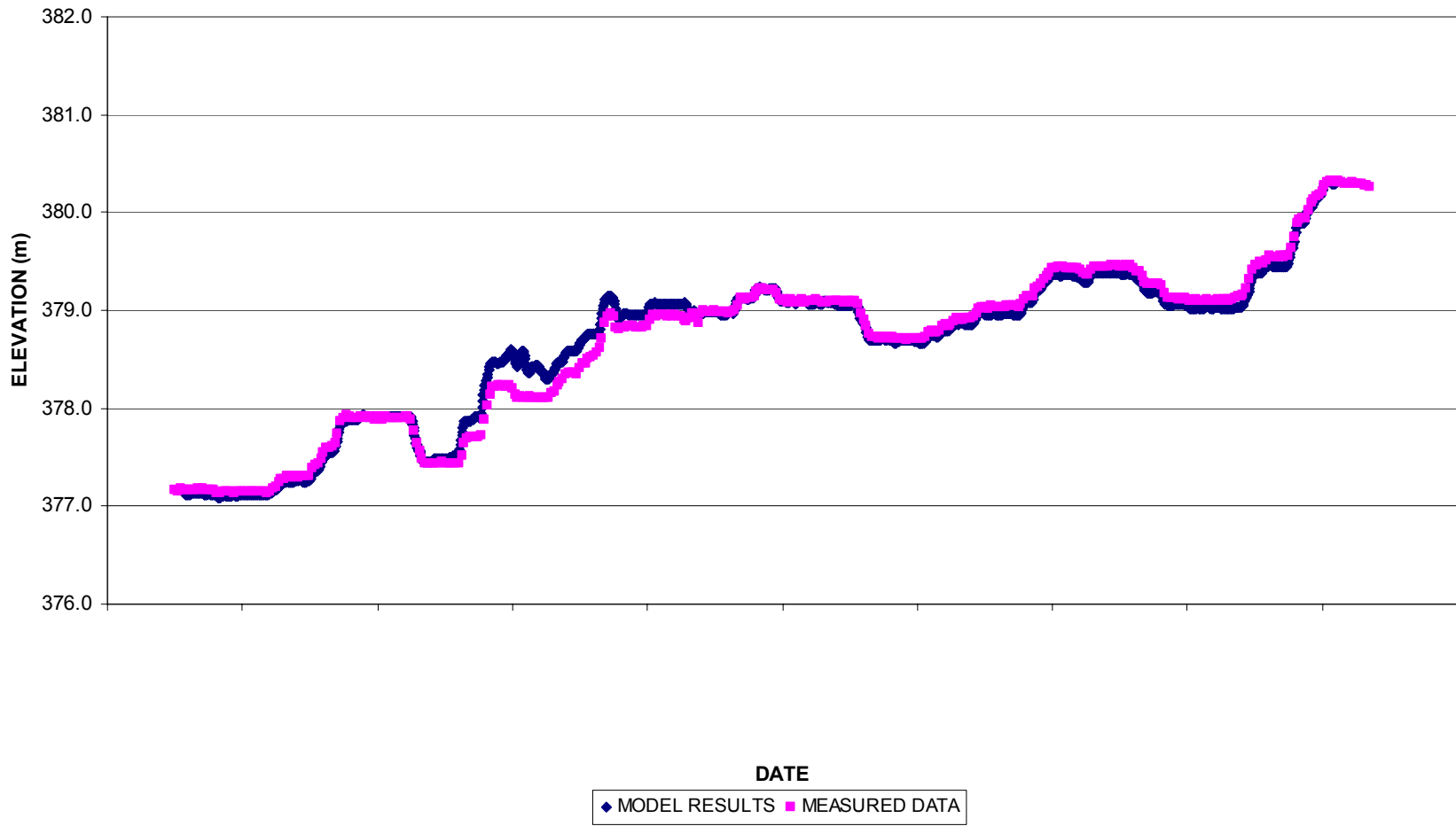
HYDRAULIC MODEL CALIBRATION - SALT CREEK PT
CHAINAGE 40571



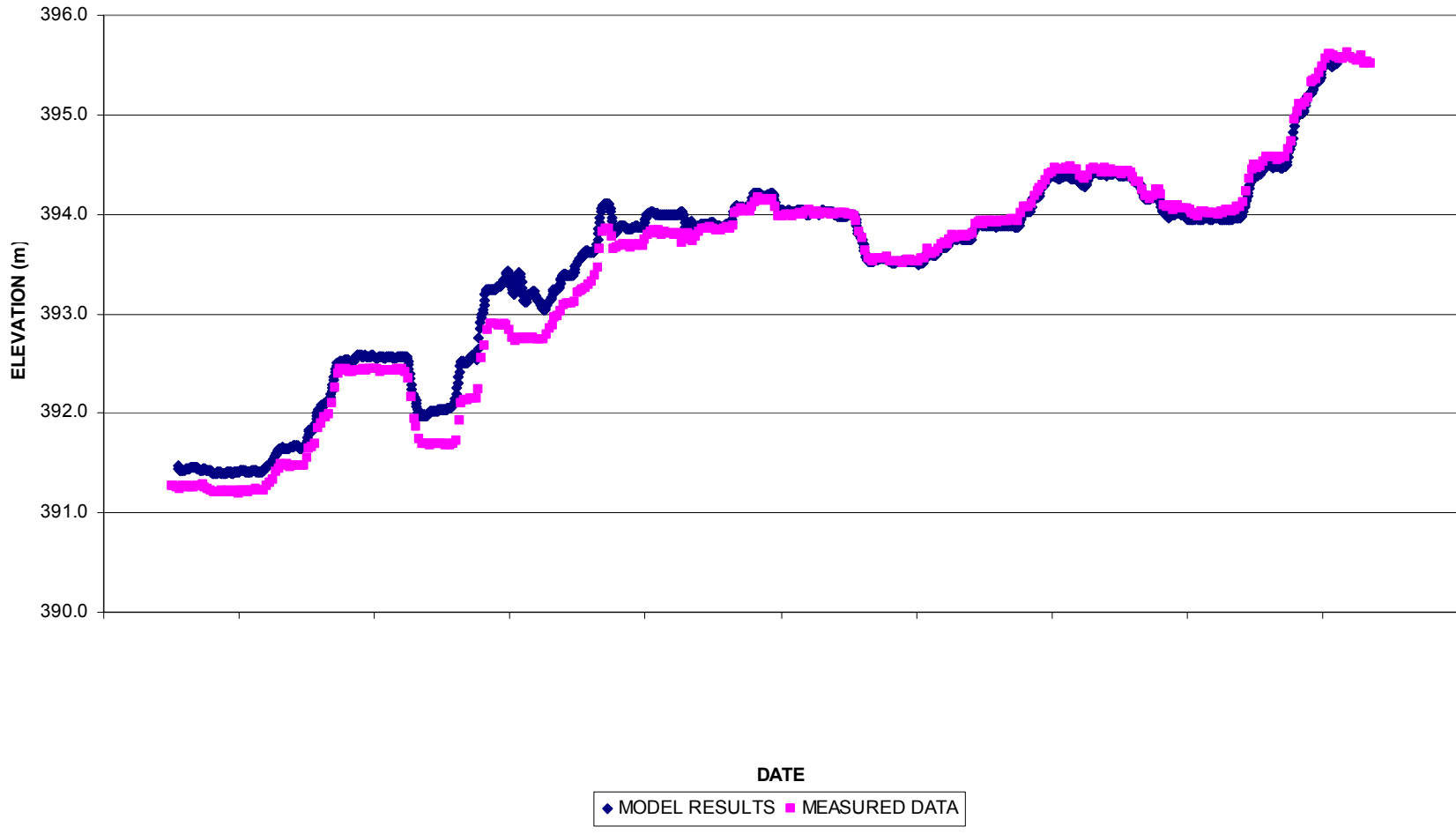
HYDRAULIC MODEL CALIBRATION - SUICIDE POINT PT CHAINAGE 39766



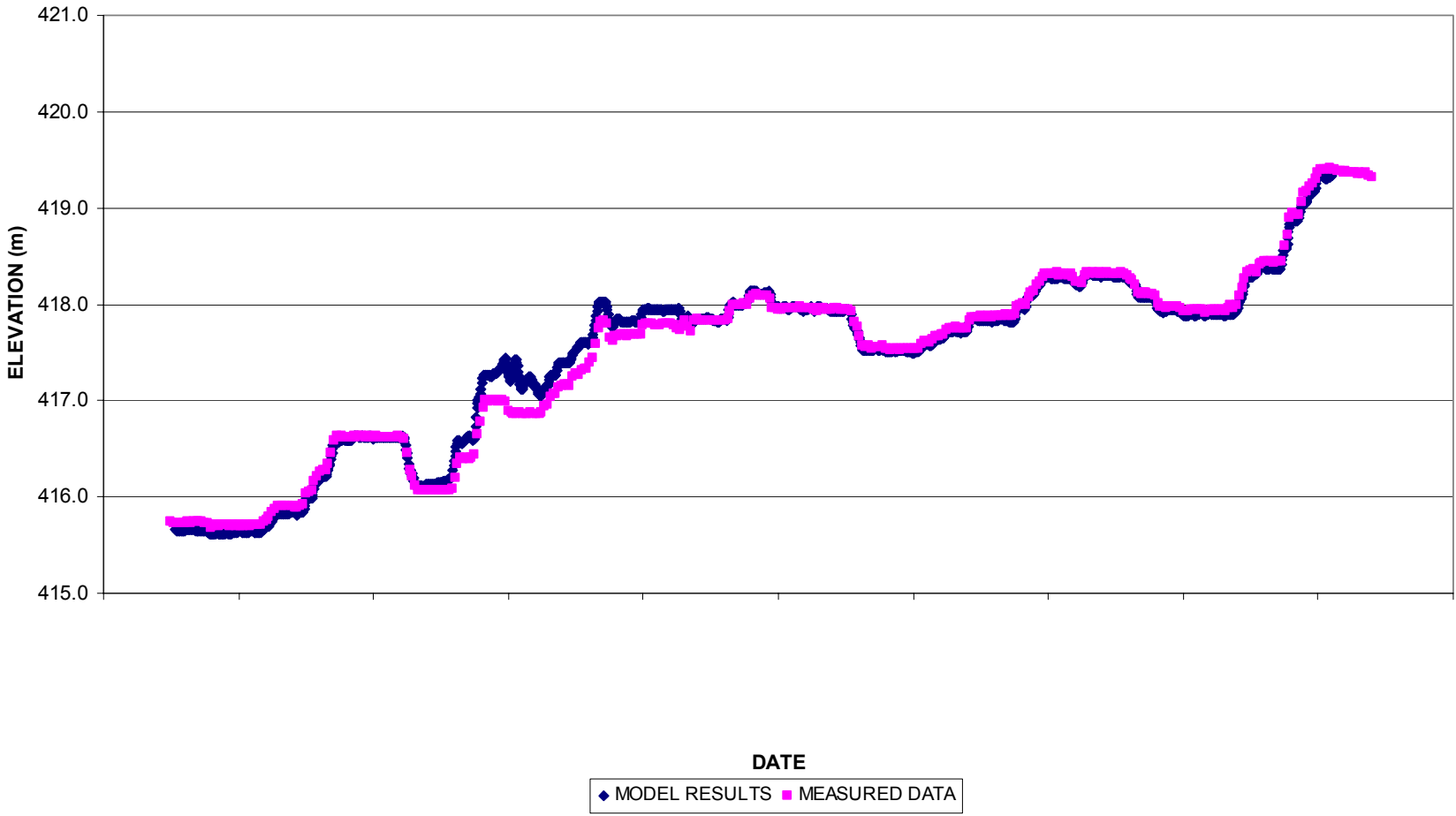
**HYDRAULIC MODEL CALIBRATION - UPPER PINE BAR PT
CHAINAGE 32478**



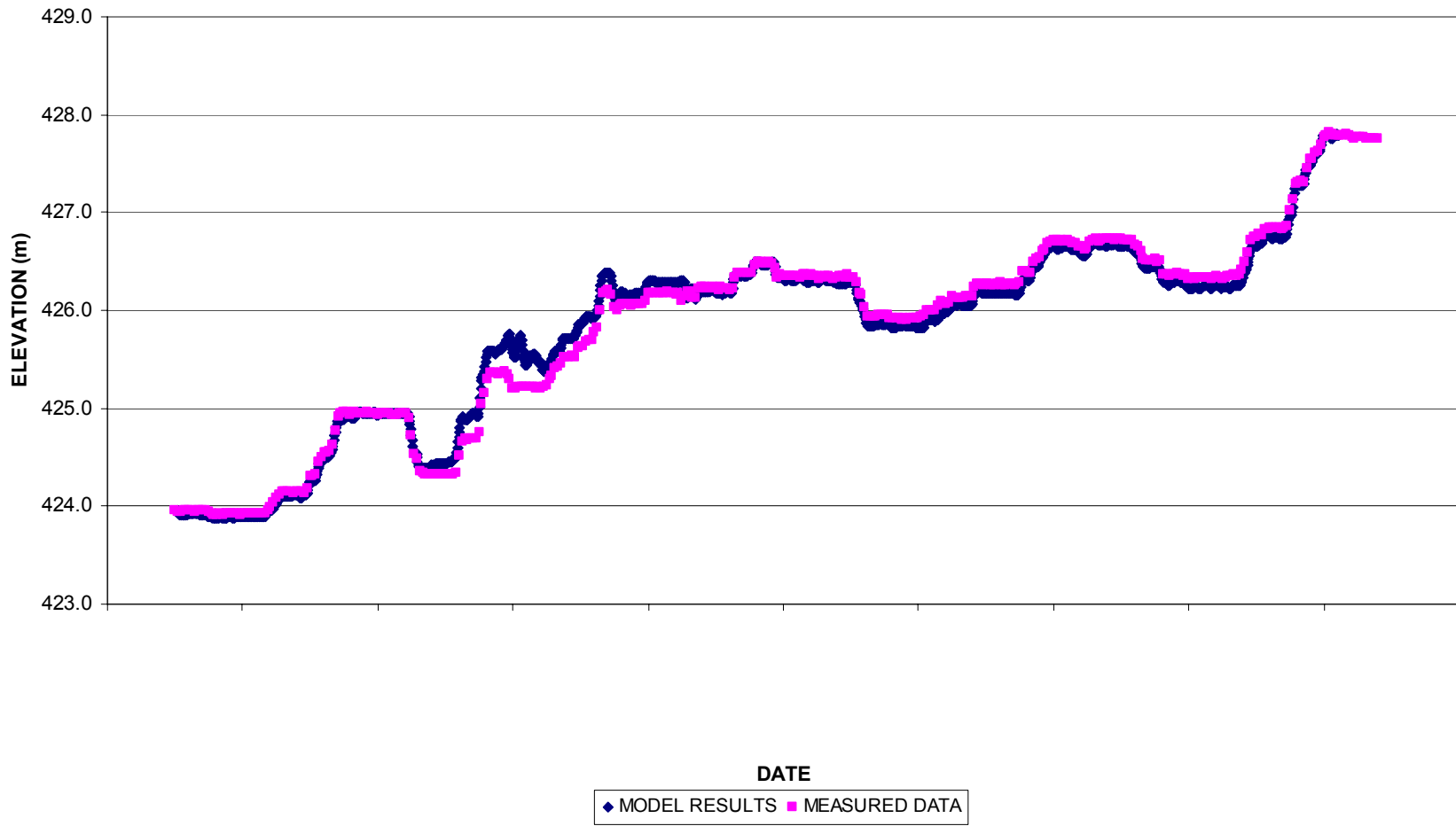
HYDRAULIC MODEL CALIBRATION - SLUICE CREEK PT
CHAINAGE 25543



**HYDRAULIC MODEL CALIBRATION - THREE CREEK PT
CHAINAGE 15177**



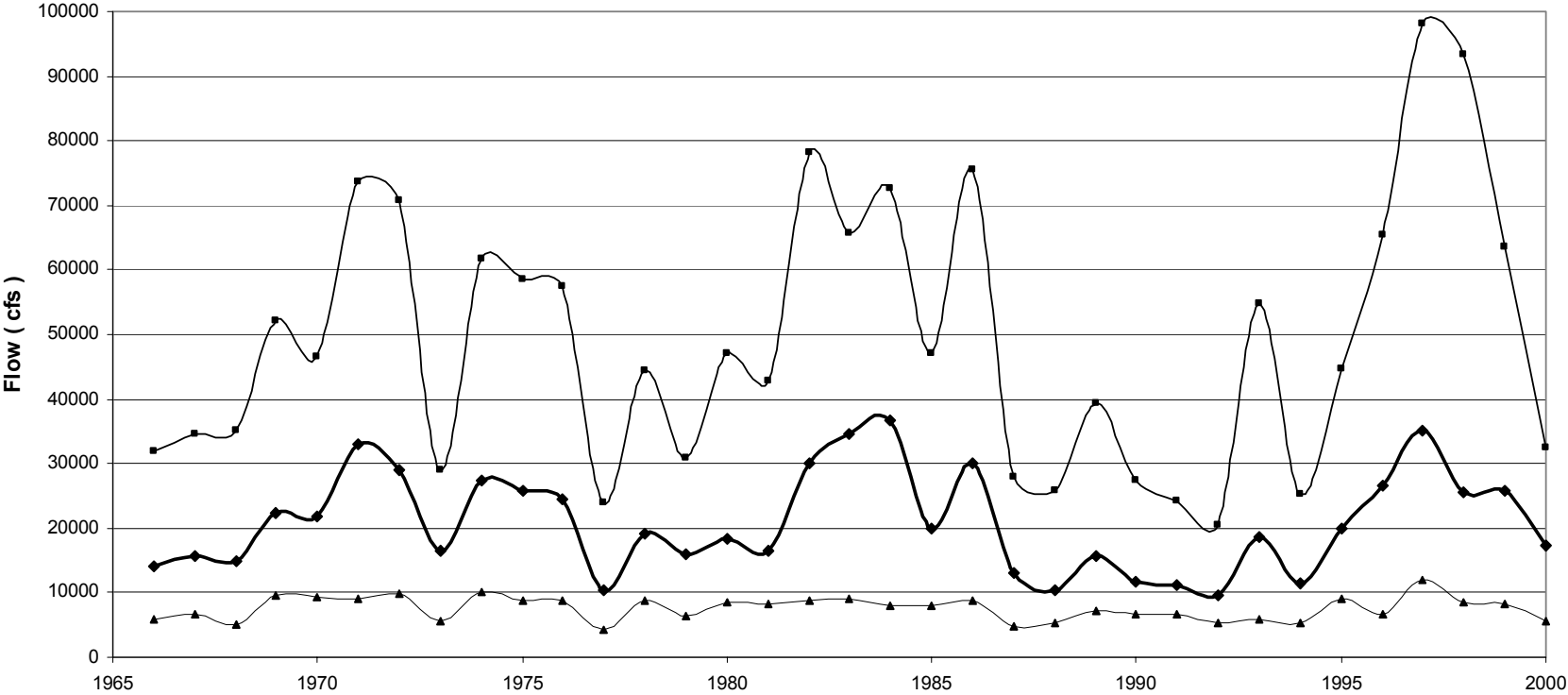
HYDRAULIC MODEL CALIBRATION - GRANITE CREEK PT
CHAINAGE 11915



Appendix 3.7. Historic Snake River Flows.

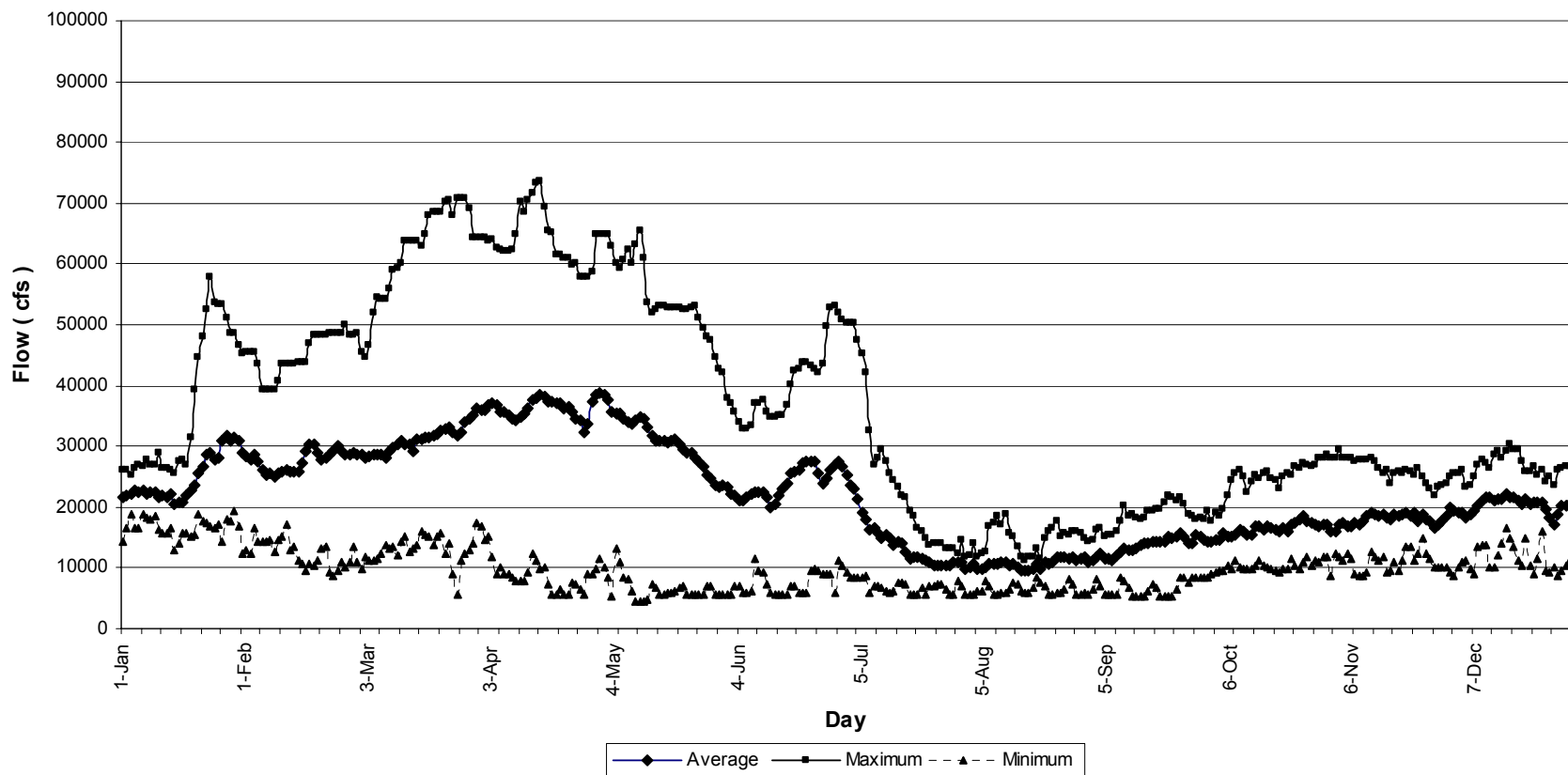
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Flow at Hells Canyon Dam - Historic

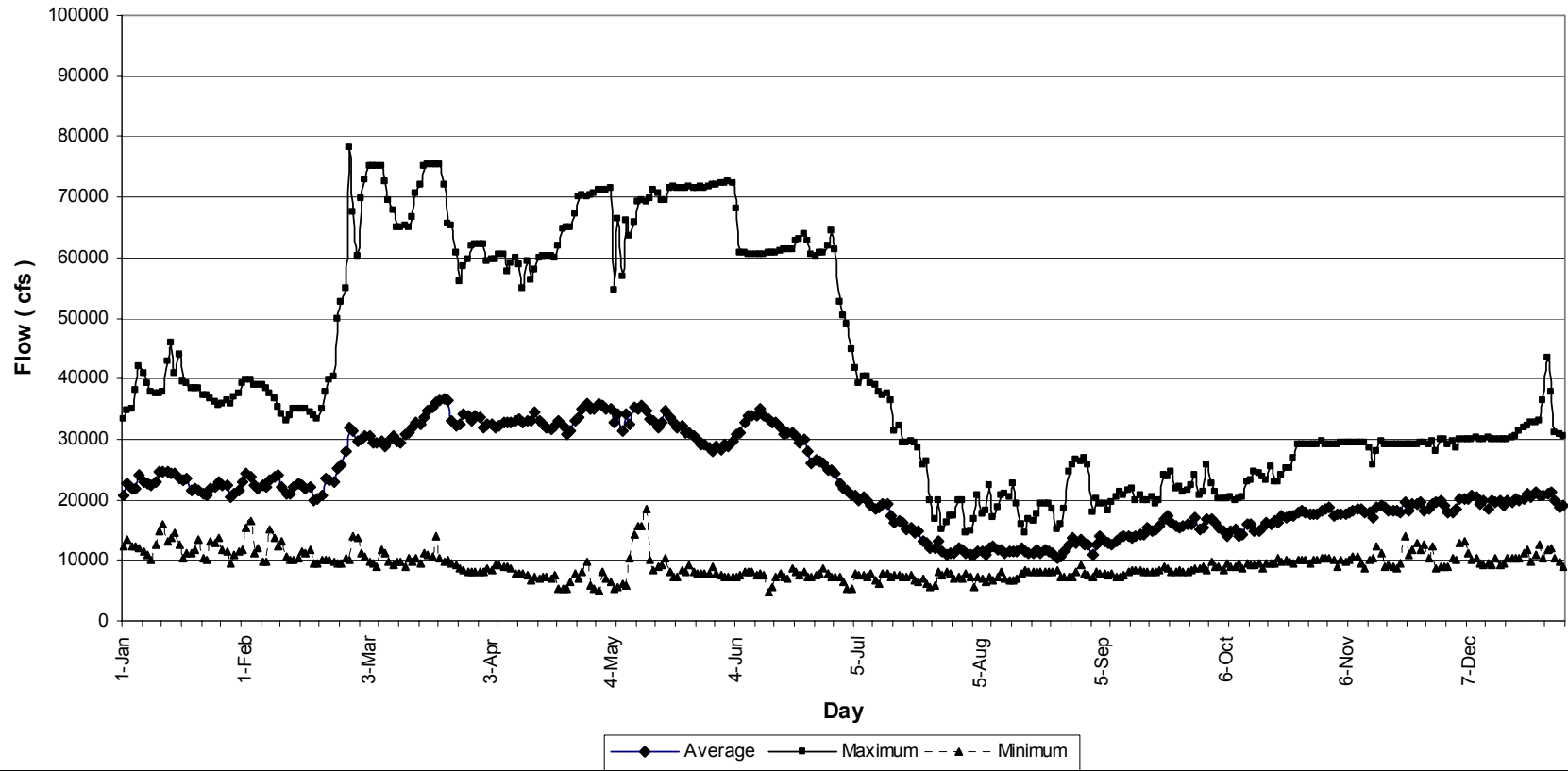


◆ Average Annual ■ Maximum Daily ▲ Minimum Daily

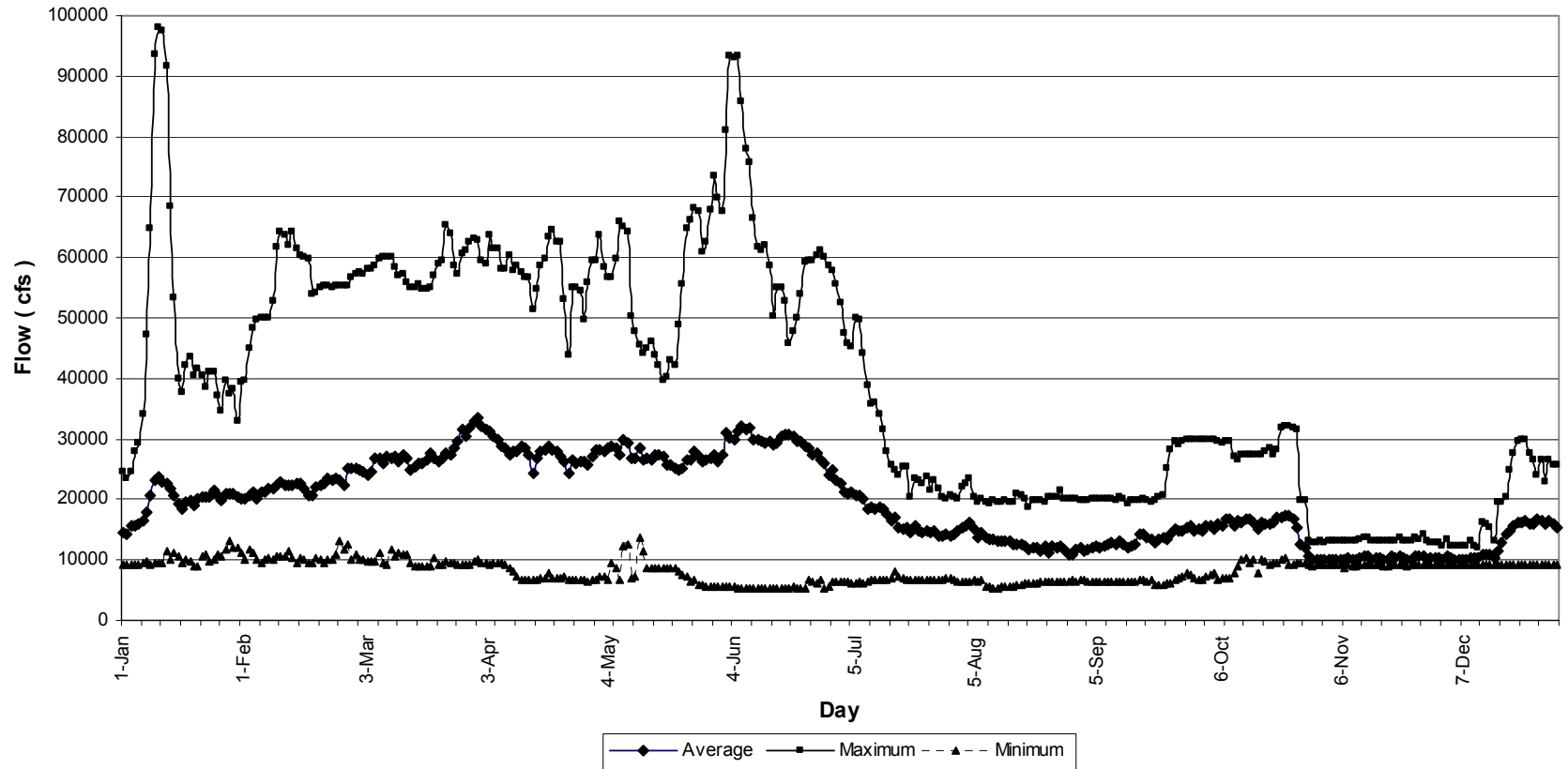
Flow at Hells Canyon Dam - Historic (1970 to 1979)



Flow at Hells Canyon Dam - Historic (1980 to 1989)



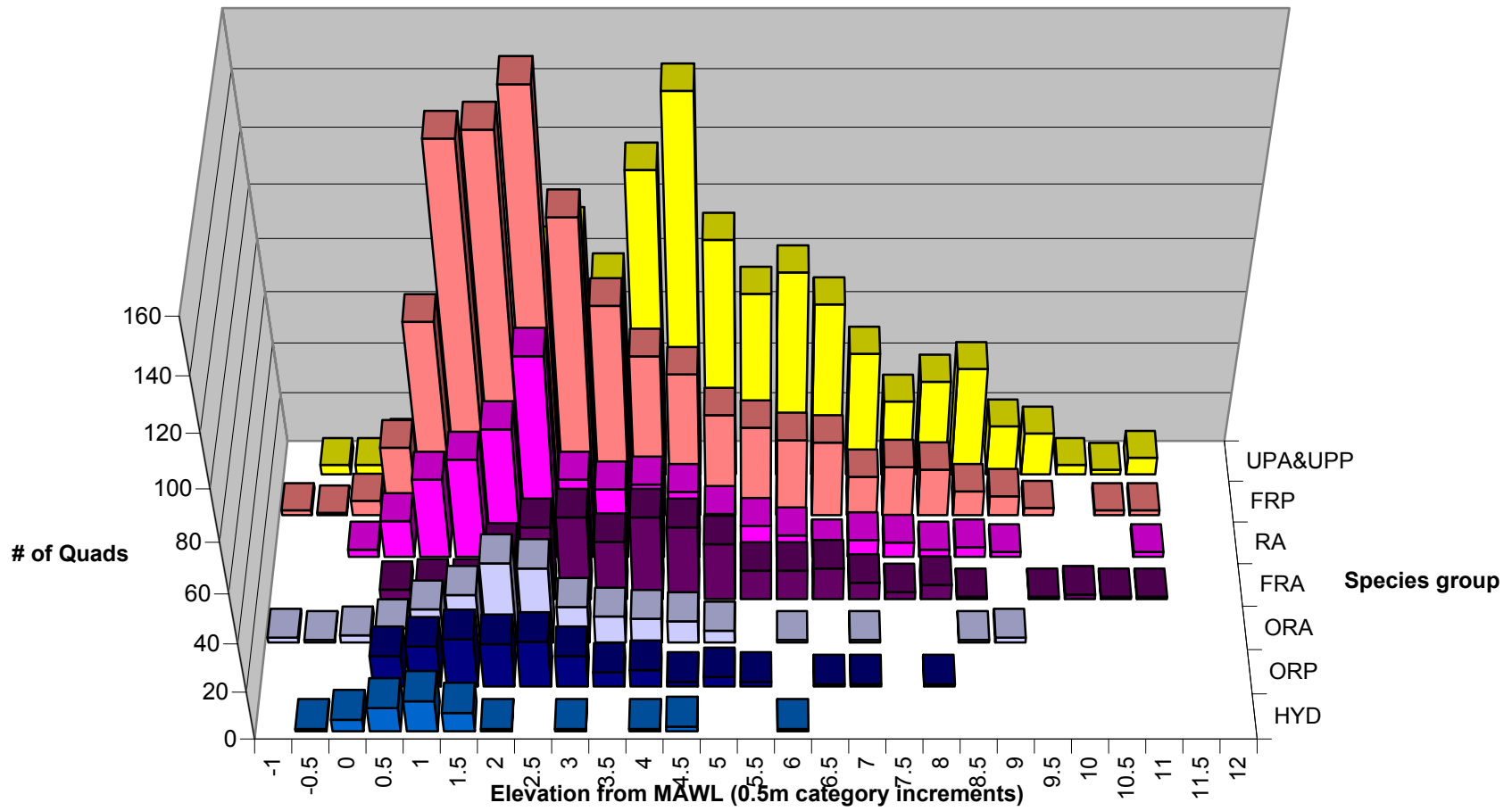
Flow at Hells Canyon Dam - Historic (1990 to 1999)



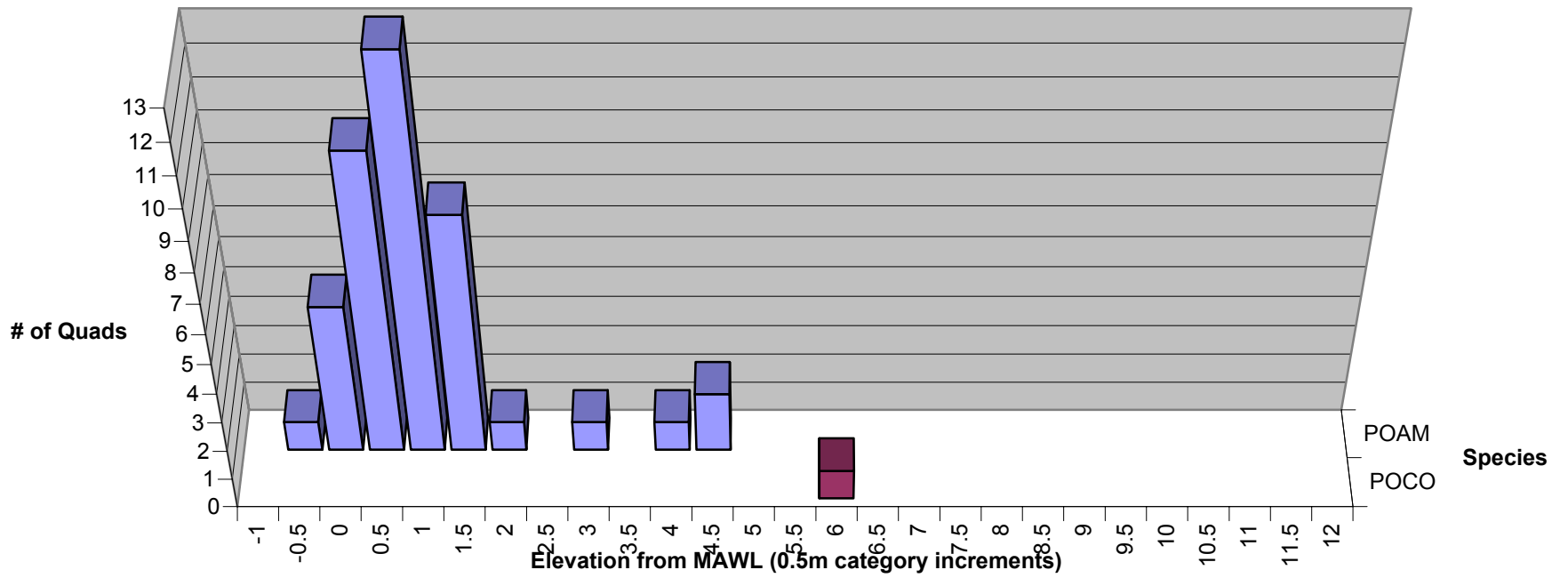
Appendix 3.8. Elevation Distributions of Vegetation (Snake River downstream of Hells Canyon Dam).

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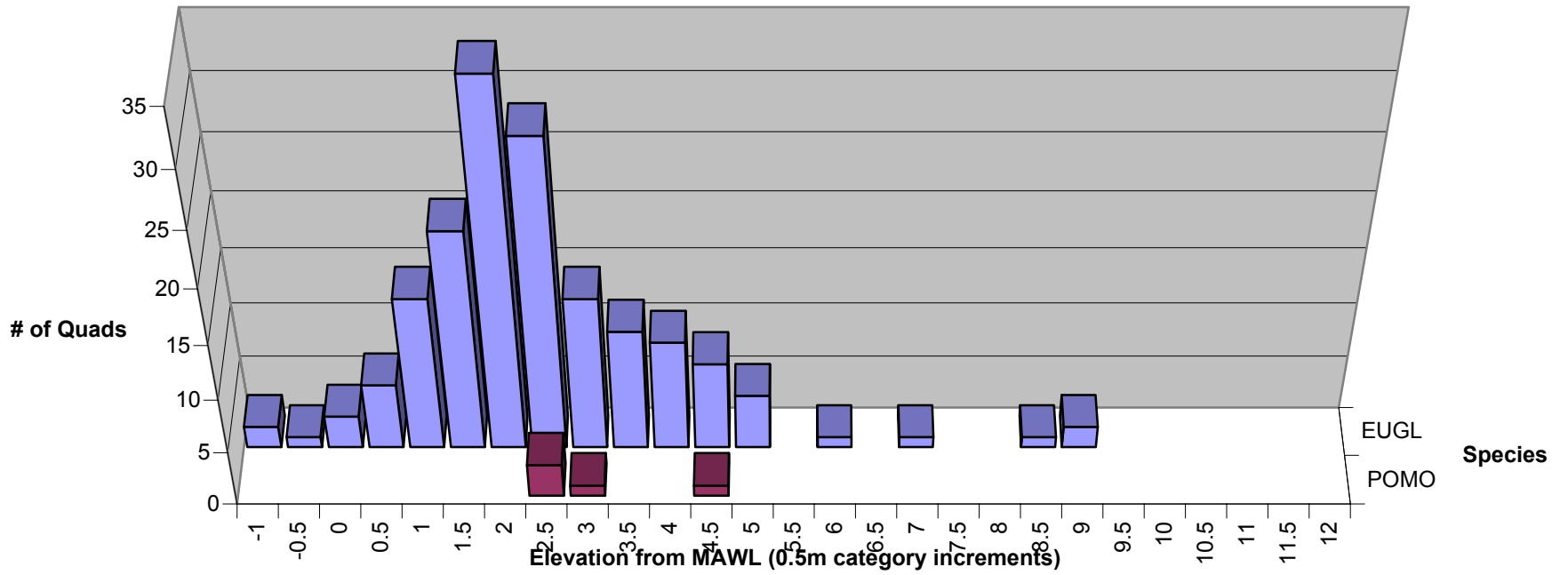
Snake River - Elevational Occurrence of Groups



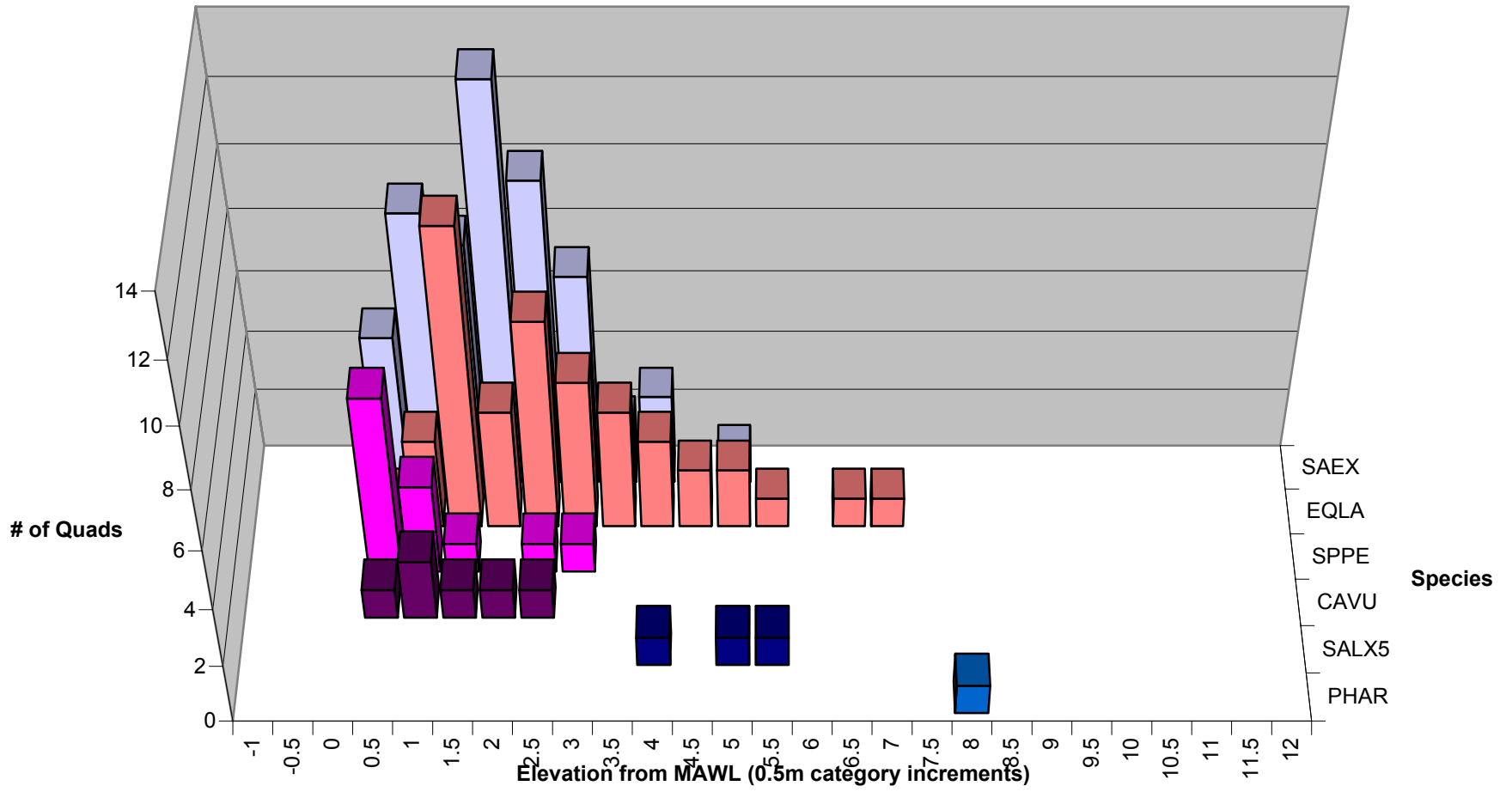
Snake River - Elevational Occurrence of HYD species



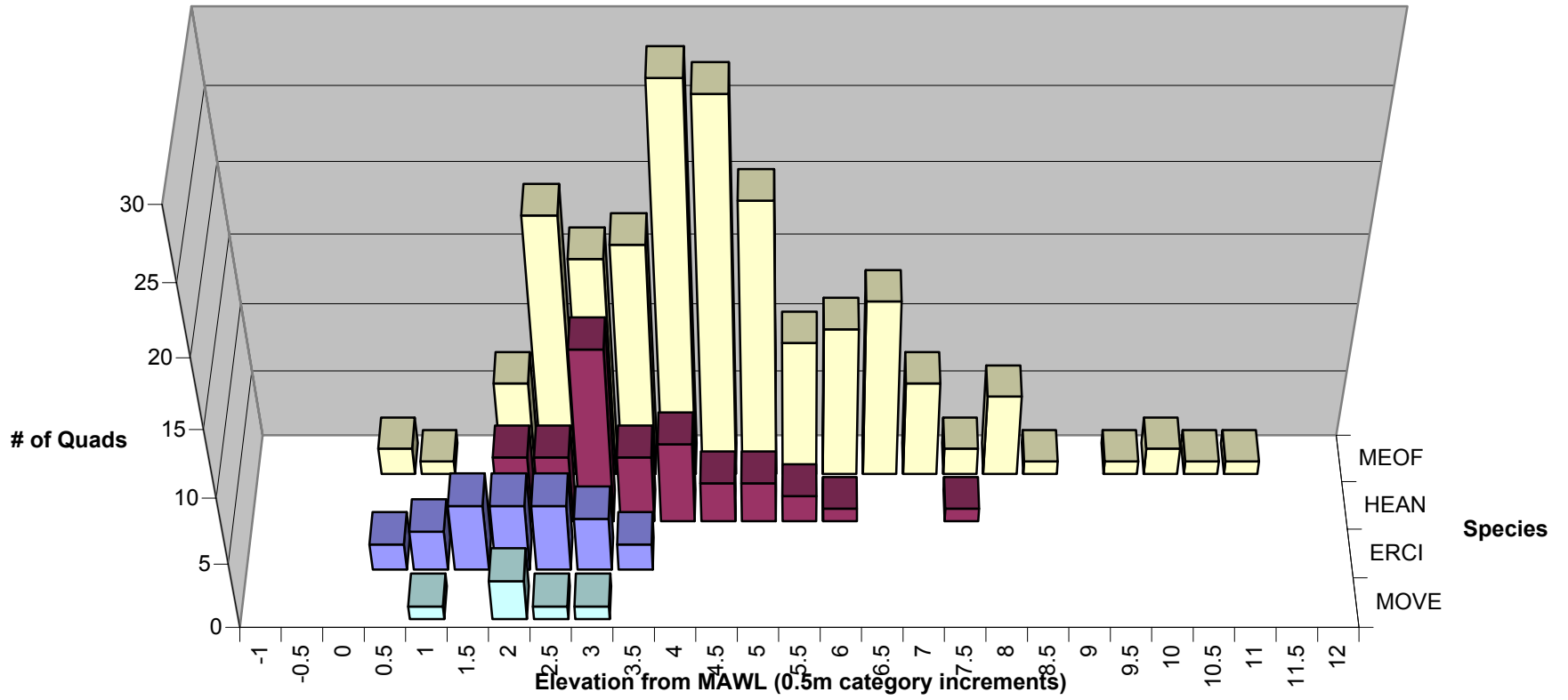
Snake River - Elevational Occurrence of ORA species



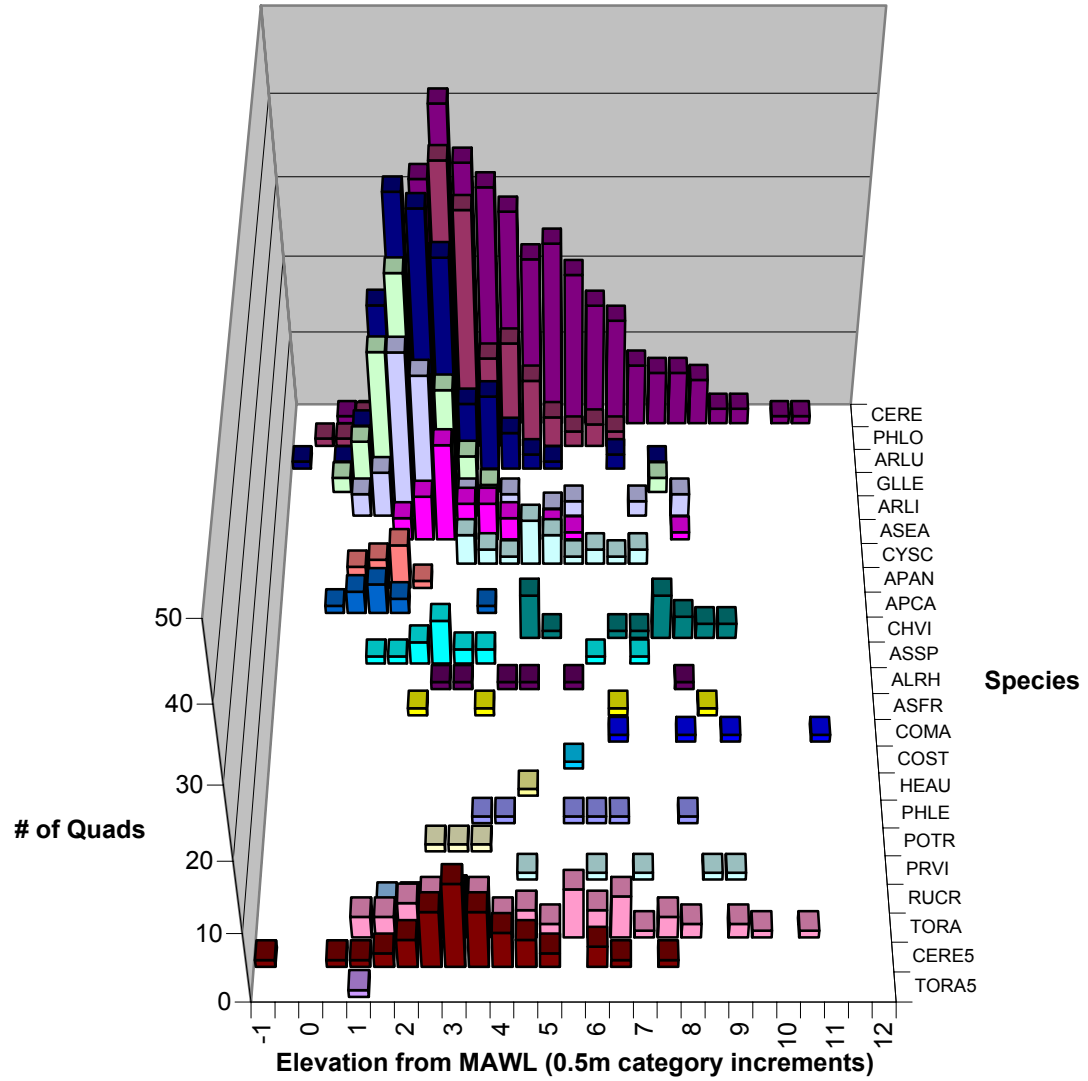
Snake River - Elevational Occurrence of ORP species



Snake River - Elevational Occurrence of FRA species



Snake River - Elevational Occurrence of FRP species

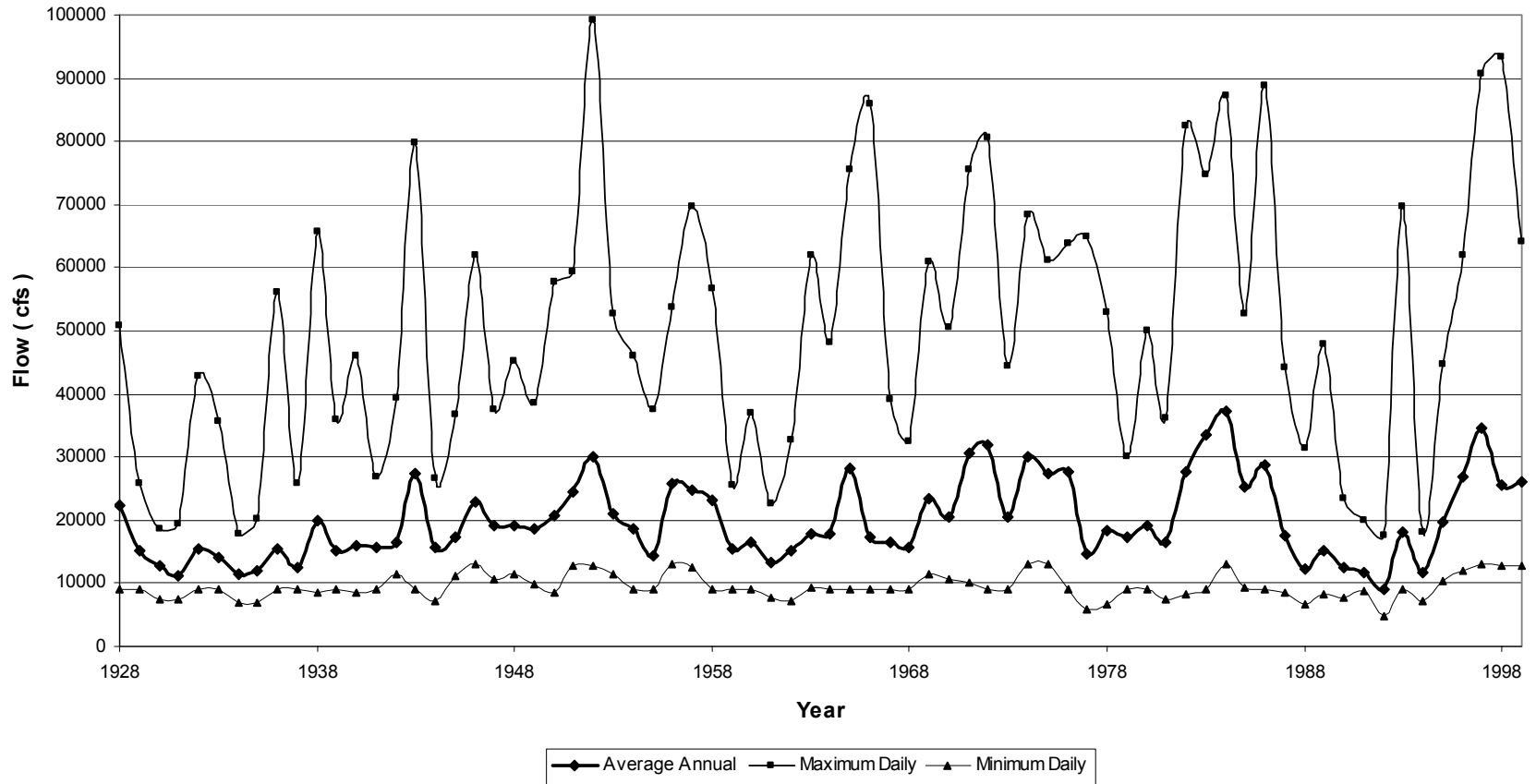


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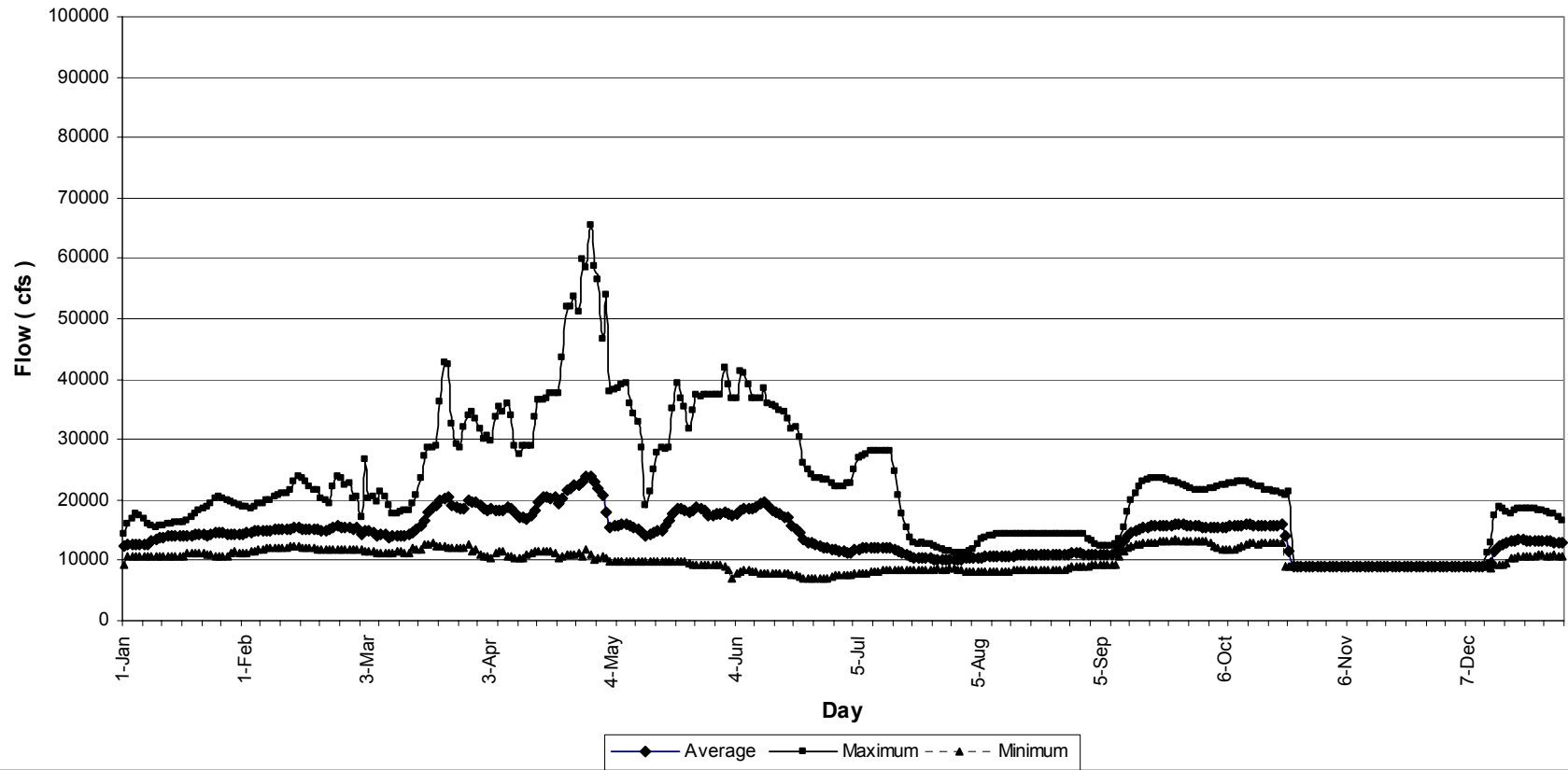
Appendix 3.9. Snake River Scenario Flows.

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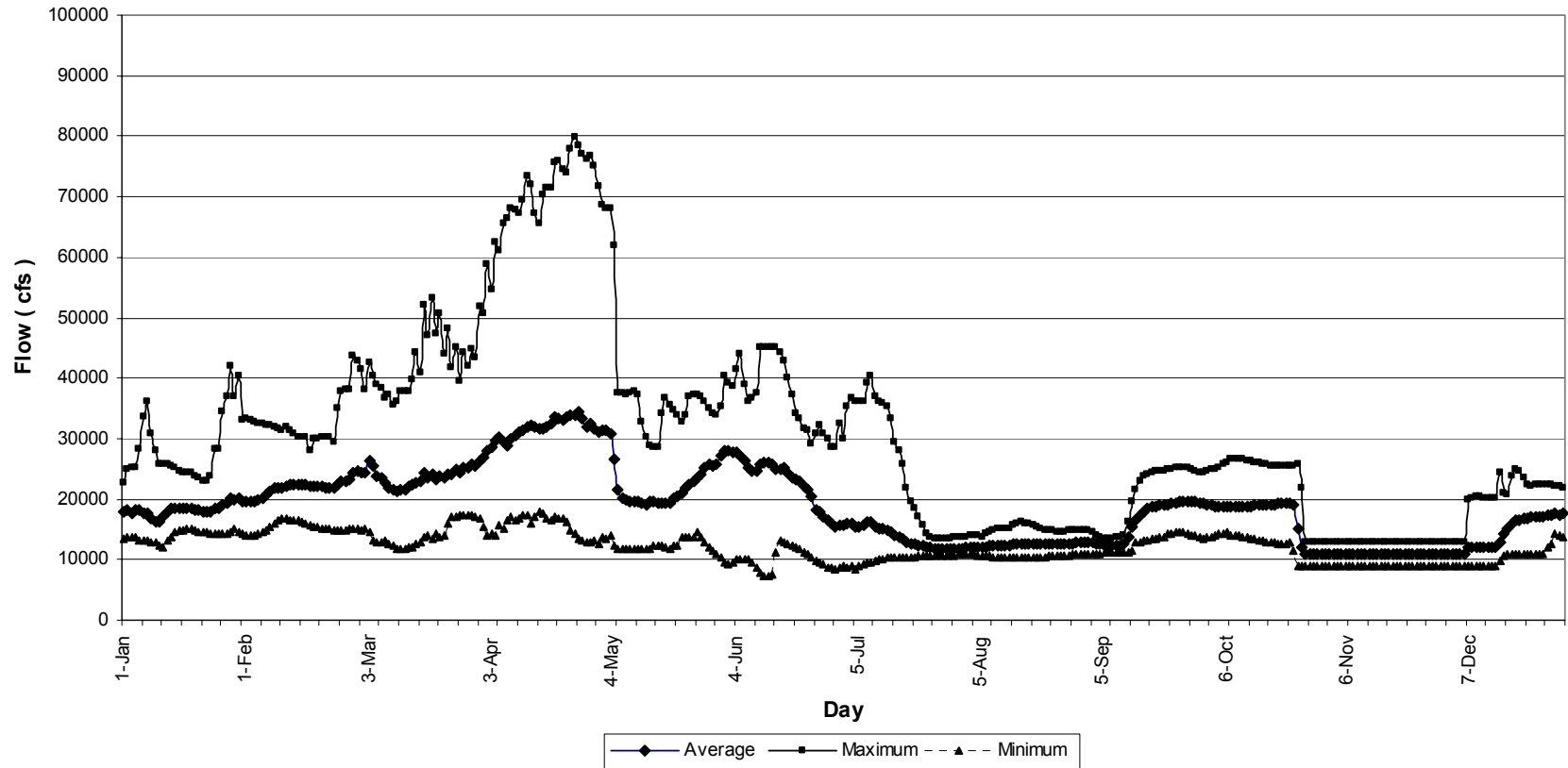
Flow at Hells Canyon Dam - Proposed



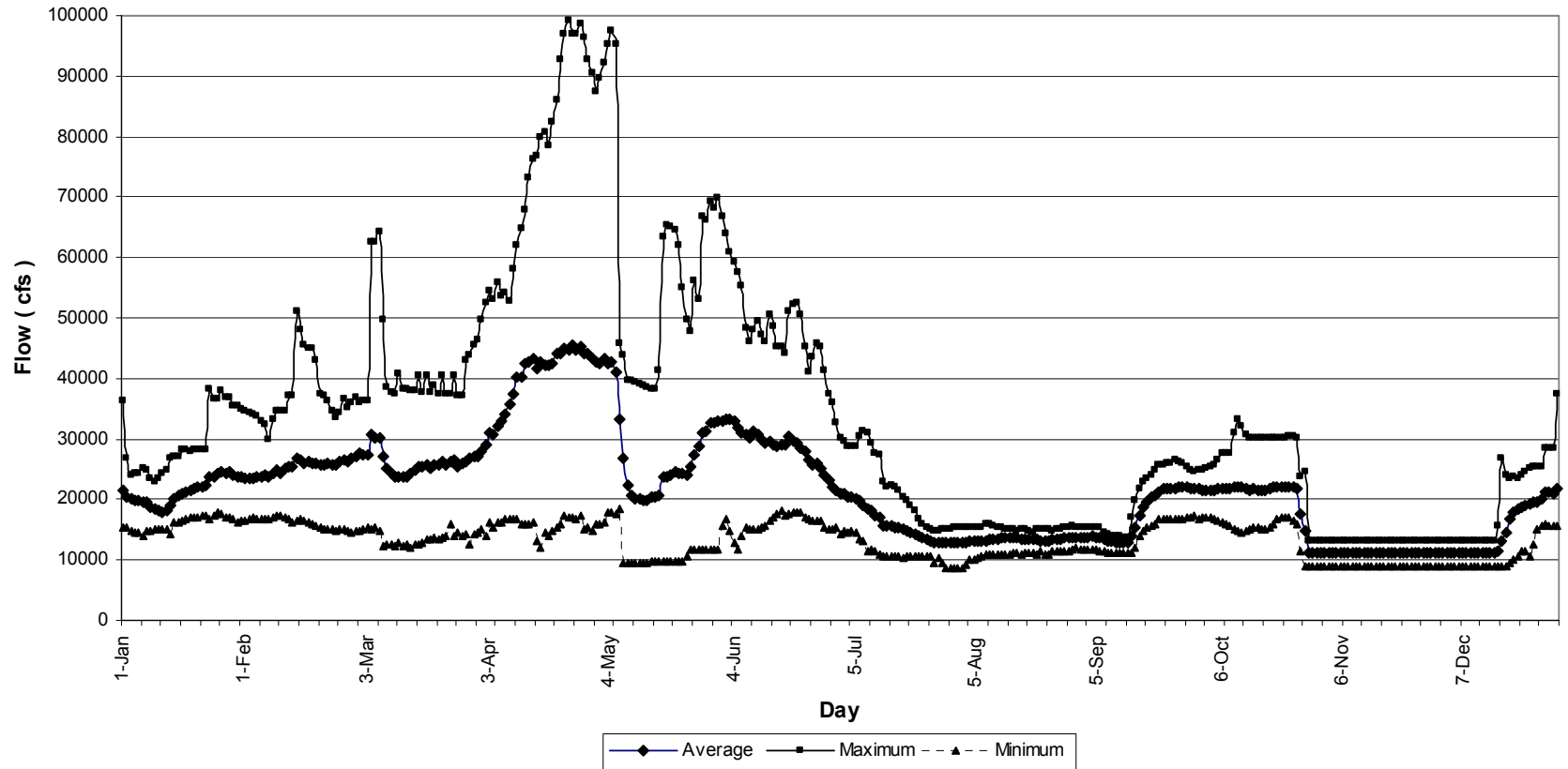
Flow at Hells Canyon Dam - Proposed (1930 to 1939)



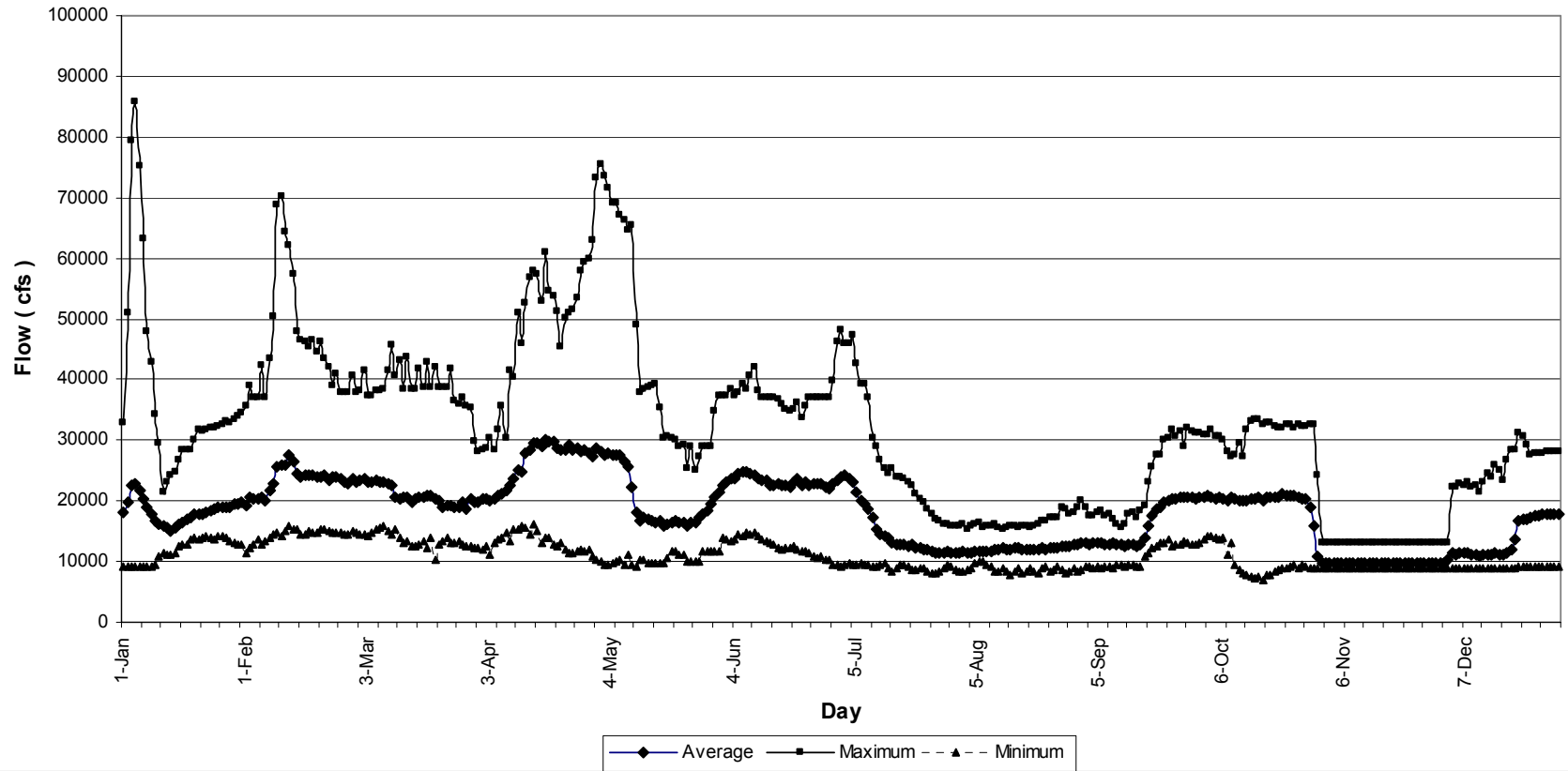
Flow at Hells Canyon Dam - Proposed (1940 to 1949)



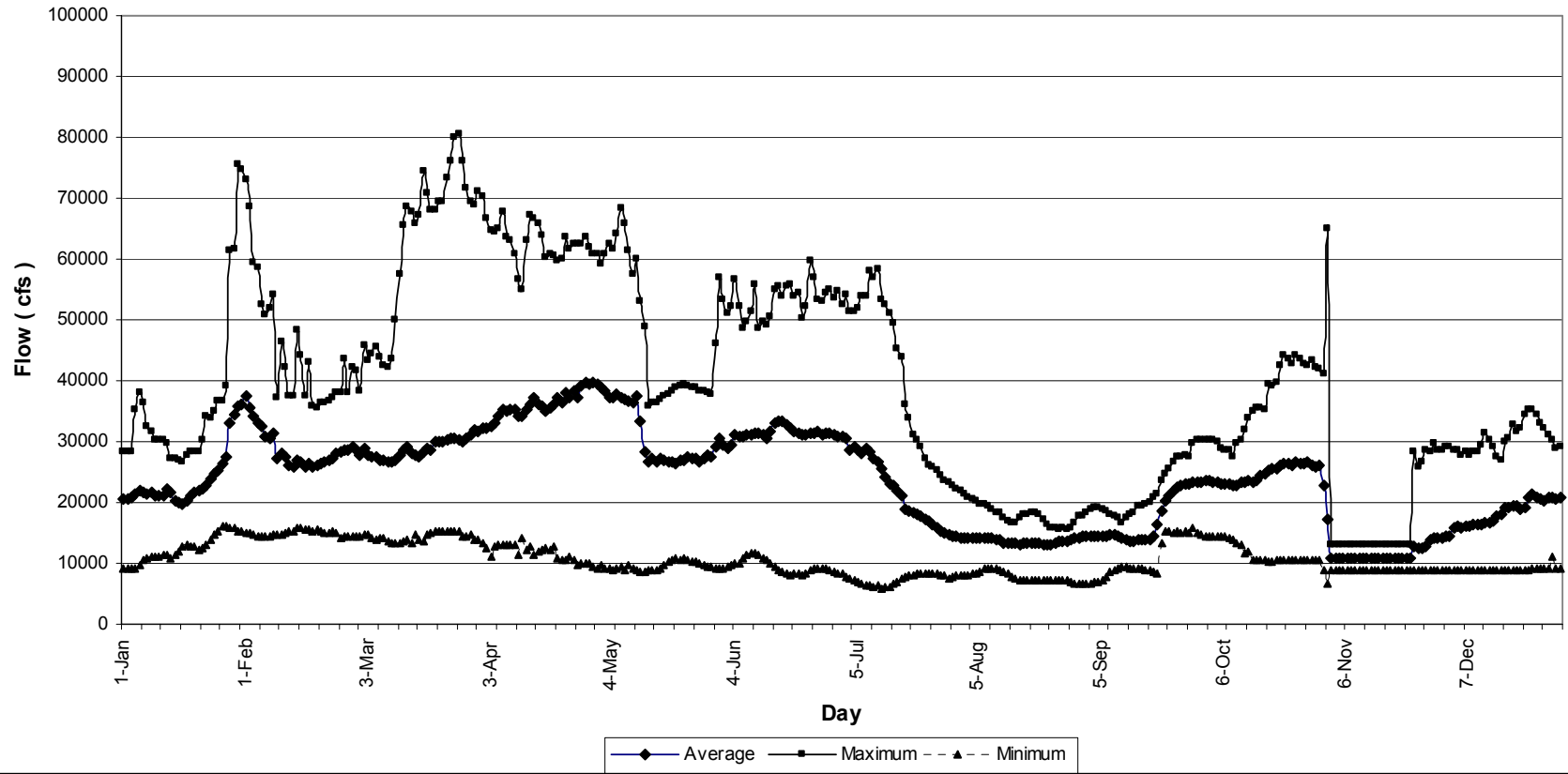
Flow at Hells Canyon Dam - Proposed (1950 to 1959)



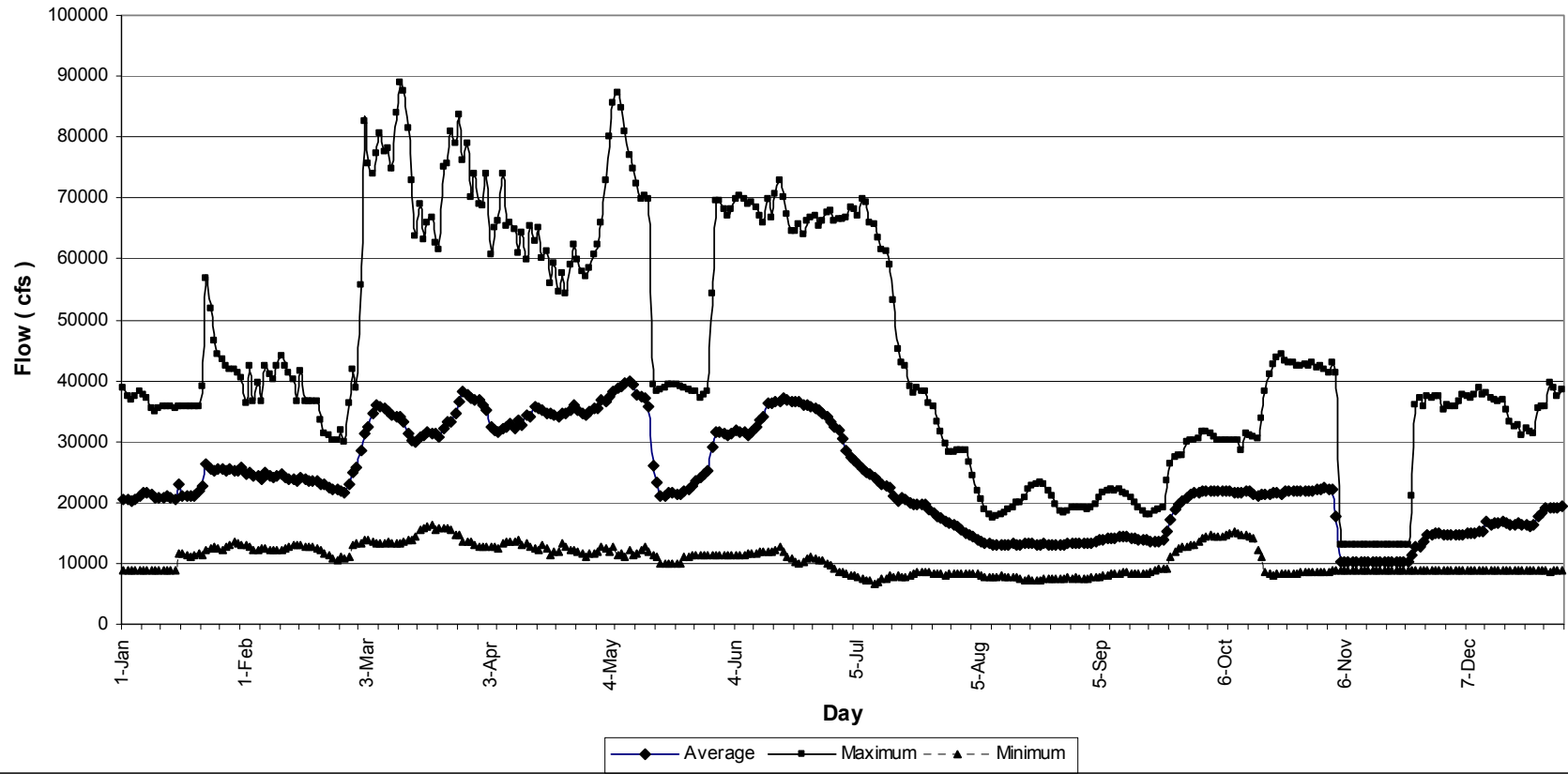
Flow at Hells Canyon Dam - Proposed (1960 to 1969)



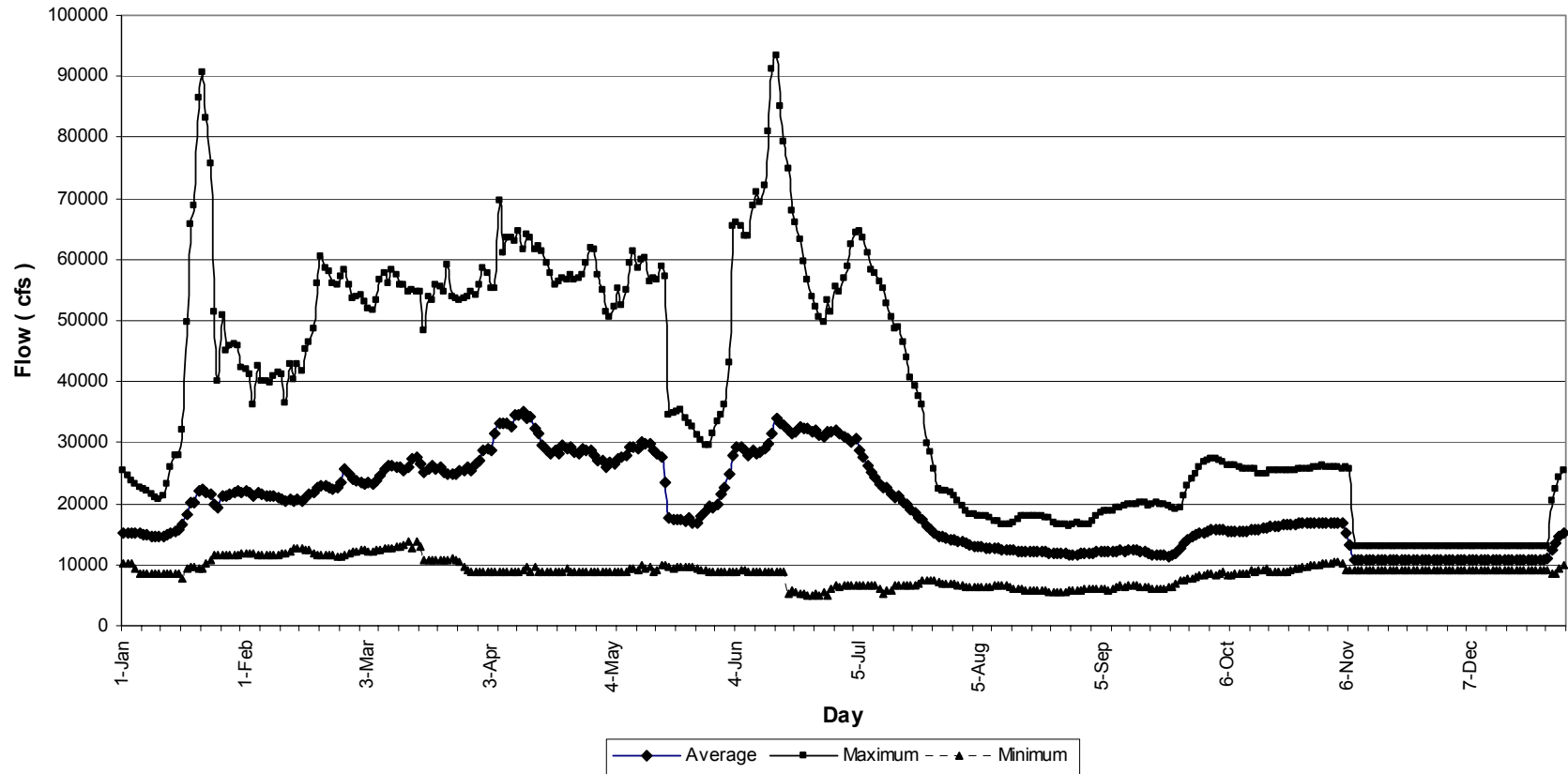
Flow at Hells Canyon Dam - Proposed (1970 to 1979)



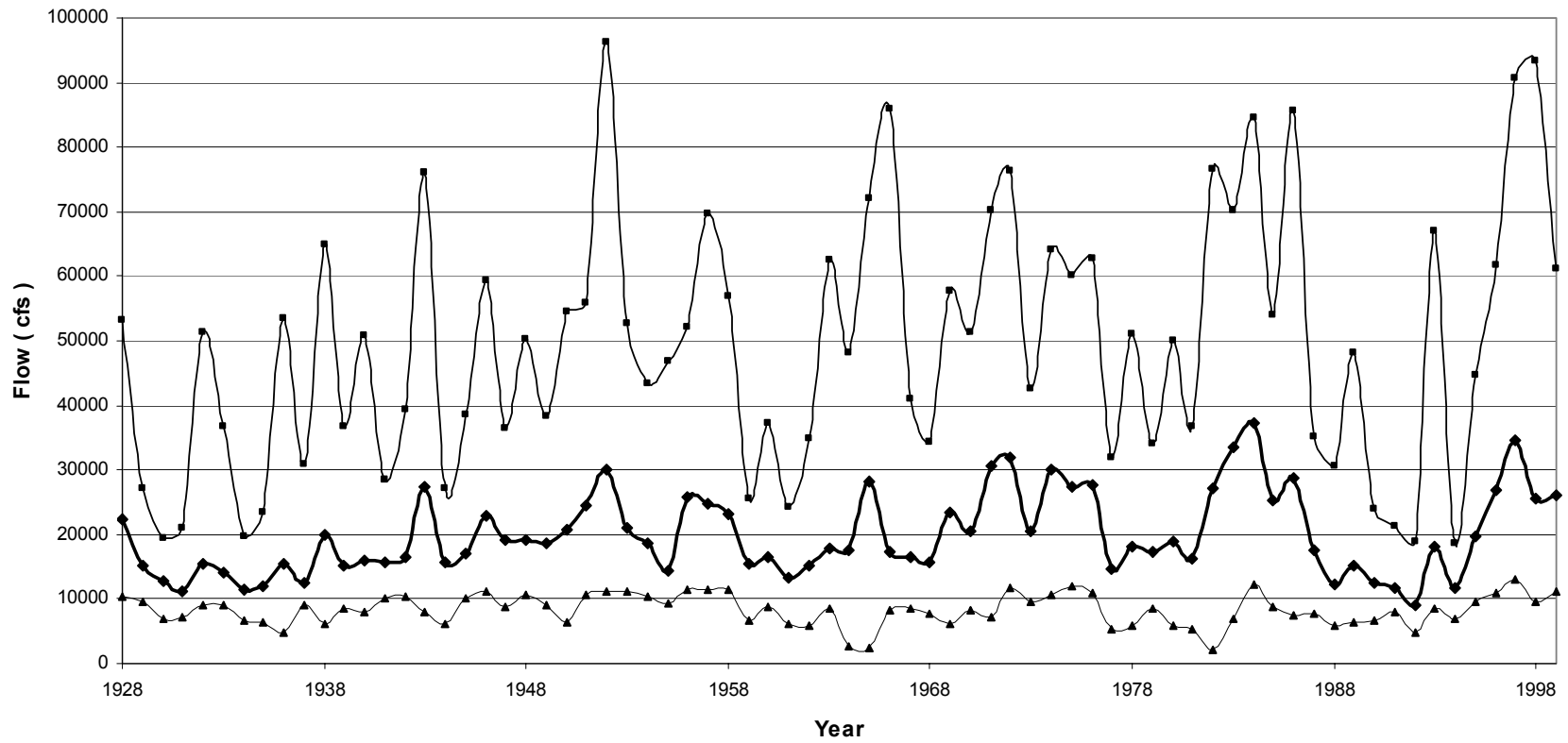
Flow at Hells Canyon Dam - Proposed (1980 to 1989)



Flow at Hells Canyon Dam - Proposed (1990 to 1999)

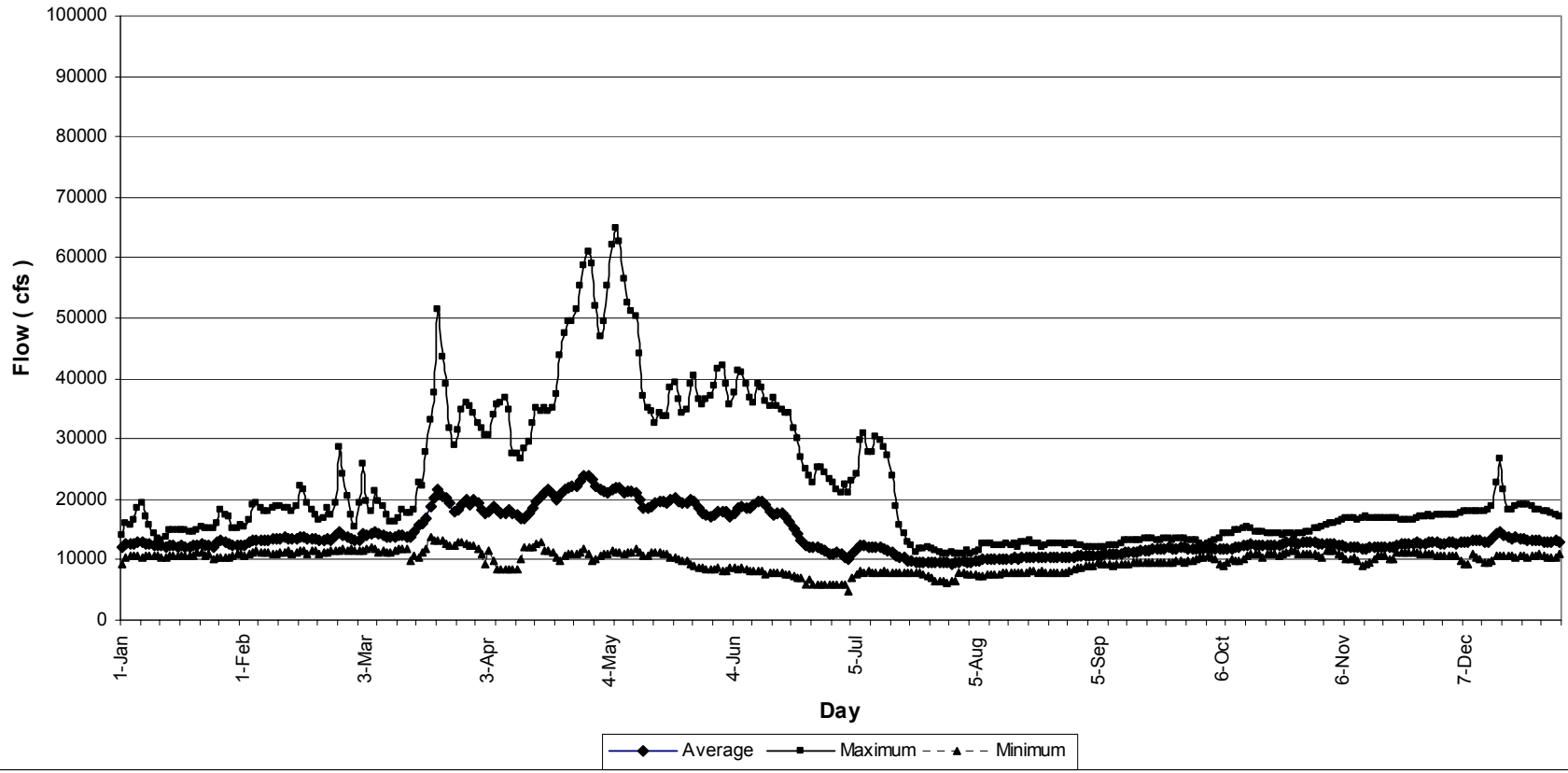


Flow at Hells Canyon Dam - Full Pool

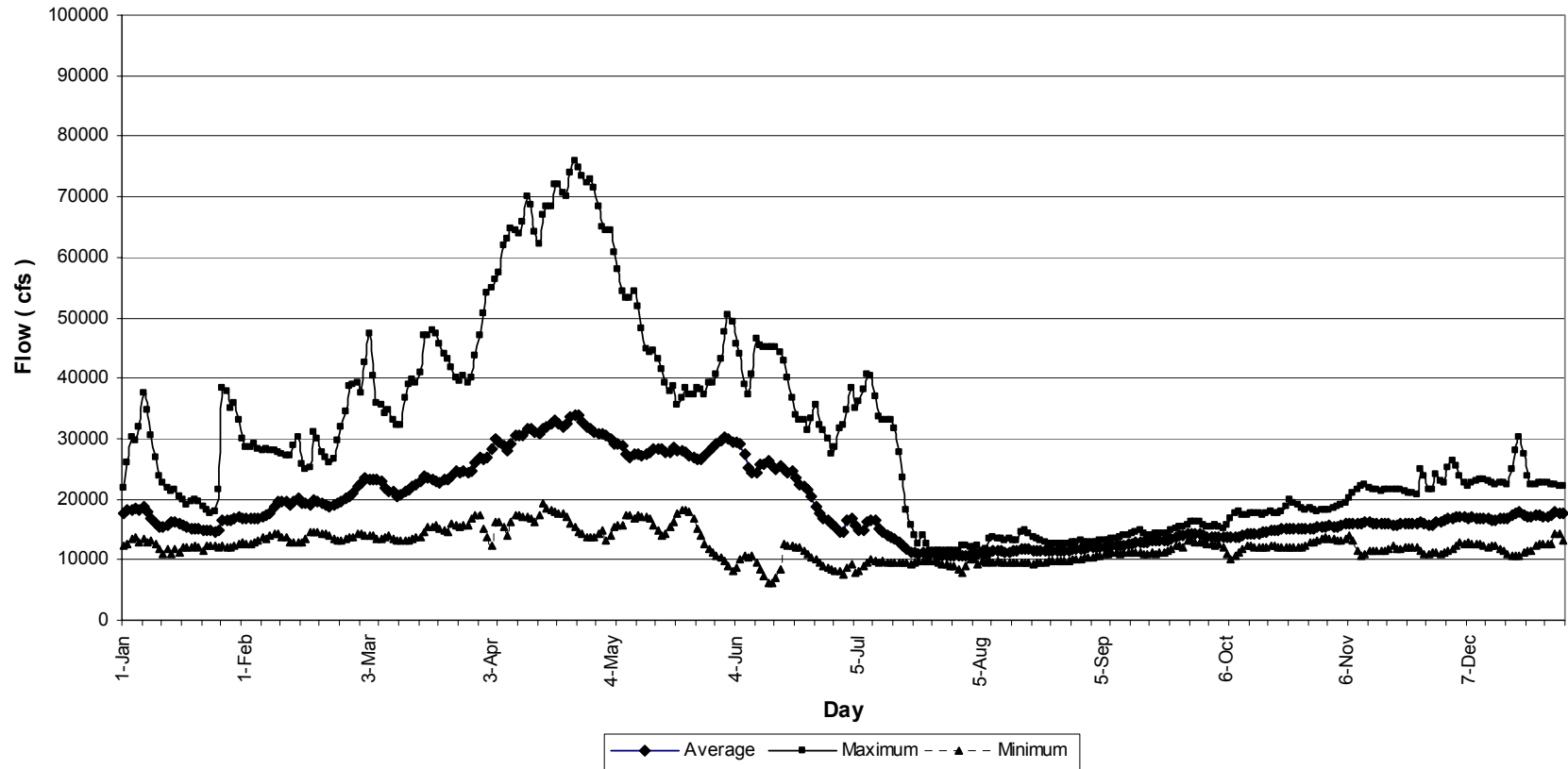


◆ Average Annual ■ Maximum Daily ▲ Minimum Daily

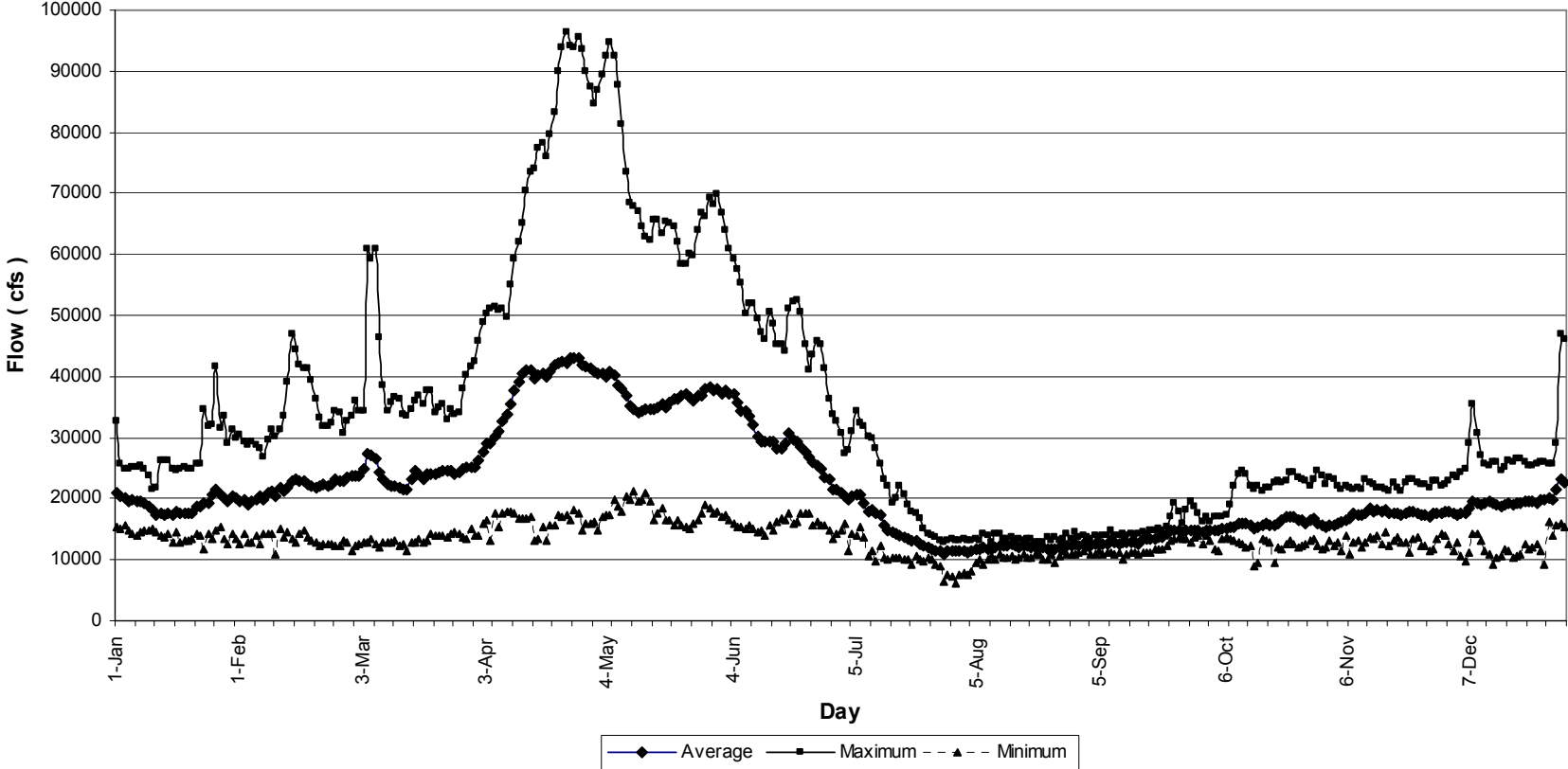
Flow at Hells Canyon Dam - Full Pool (1930 to 1939)



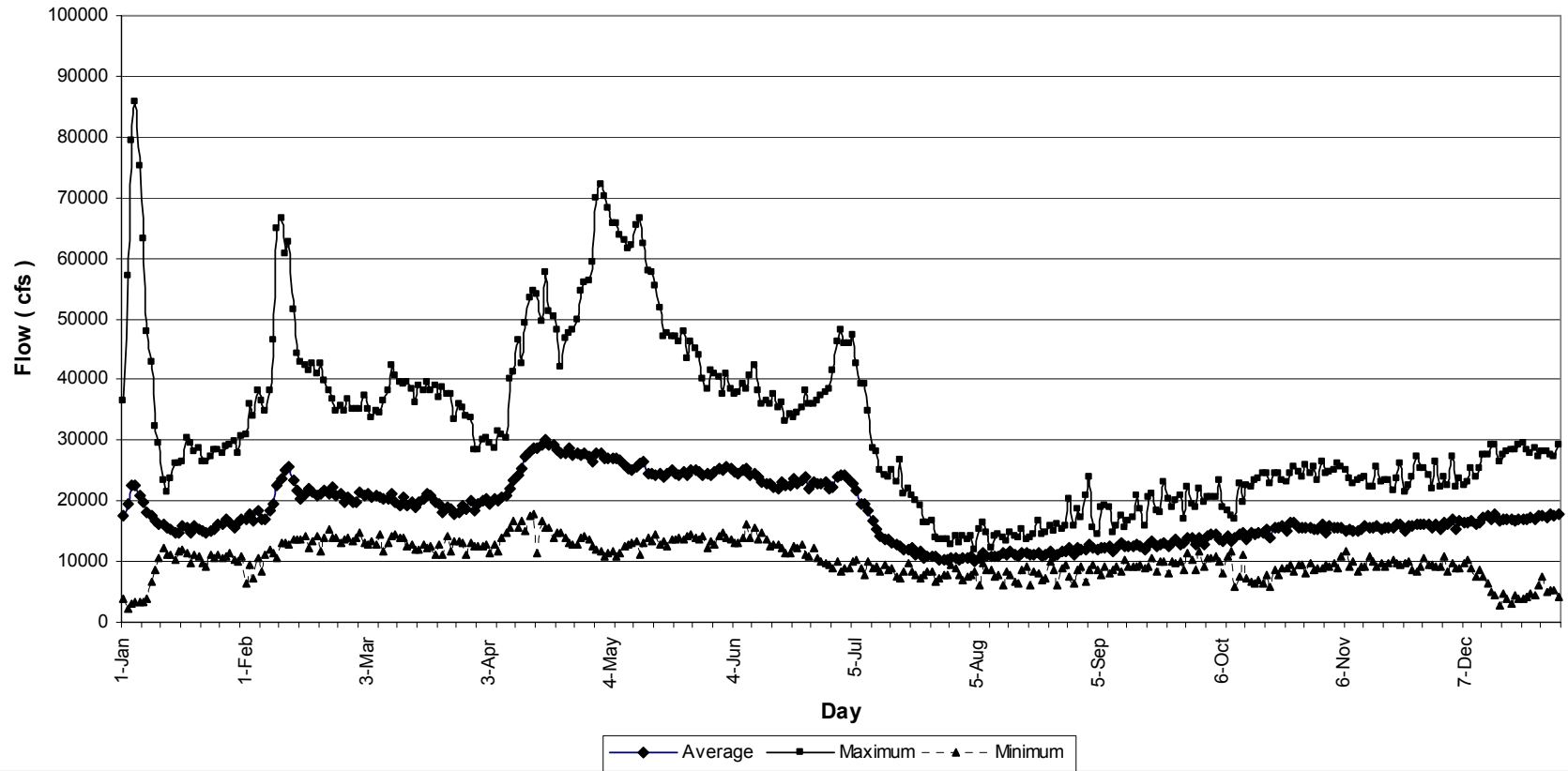
Flow at Hells Canyon Dam - Full Pool (1940 to 1949)



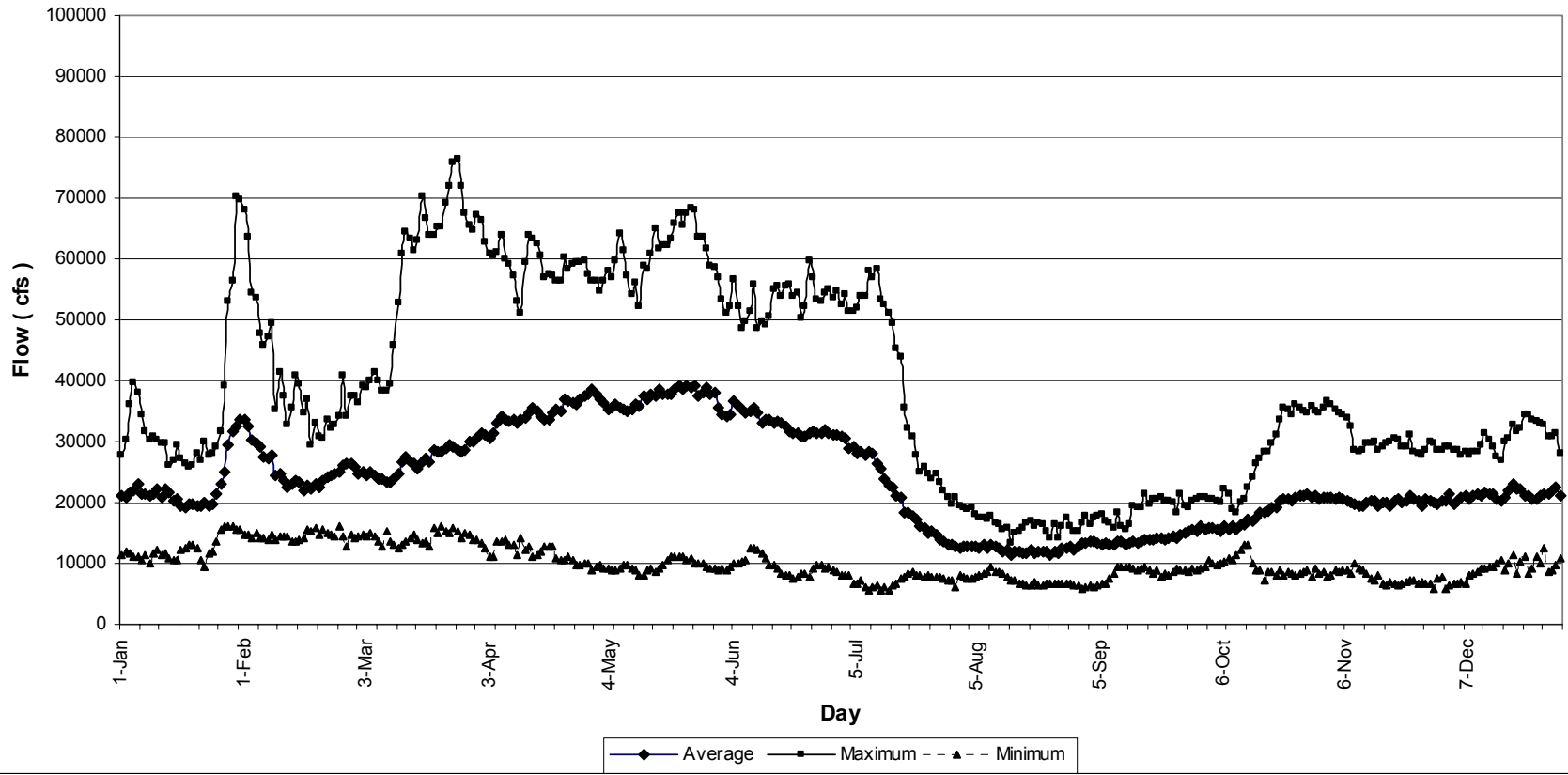
Flow at Hells Canyon Dam - Full Pool (1950 to 1959)



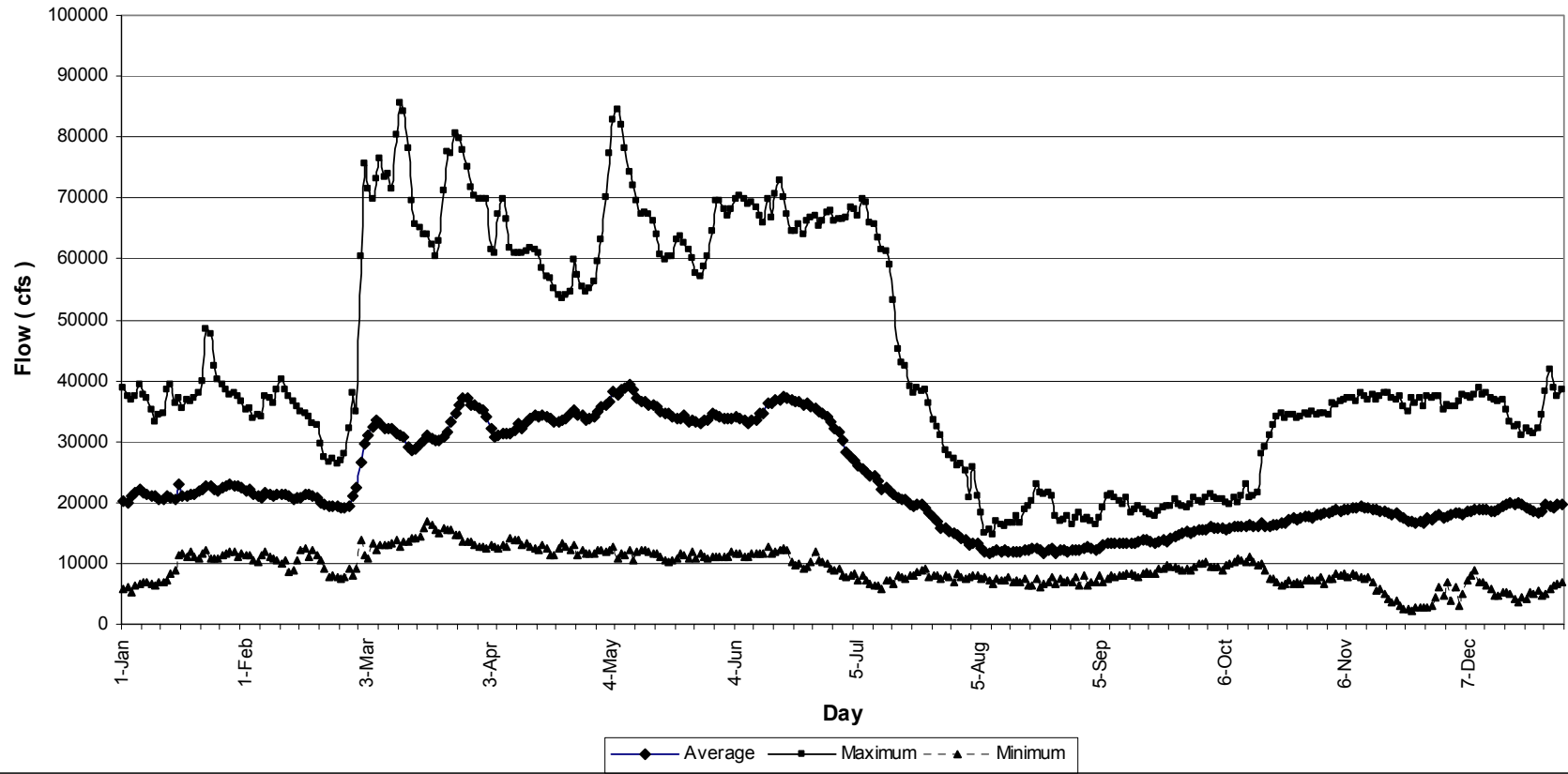
Flow at Hells Canyon Dam- Full Pool (1960 to 1969)



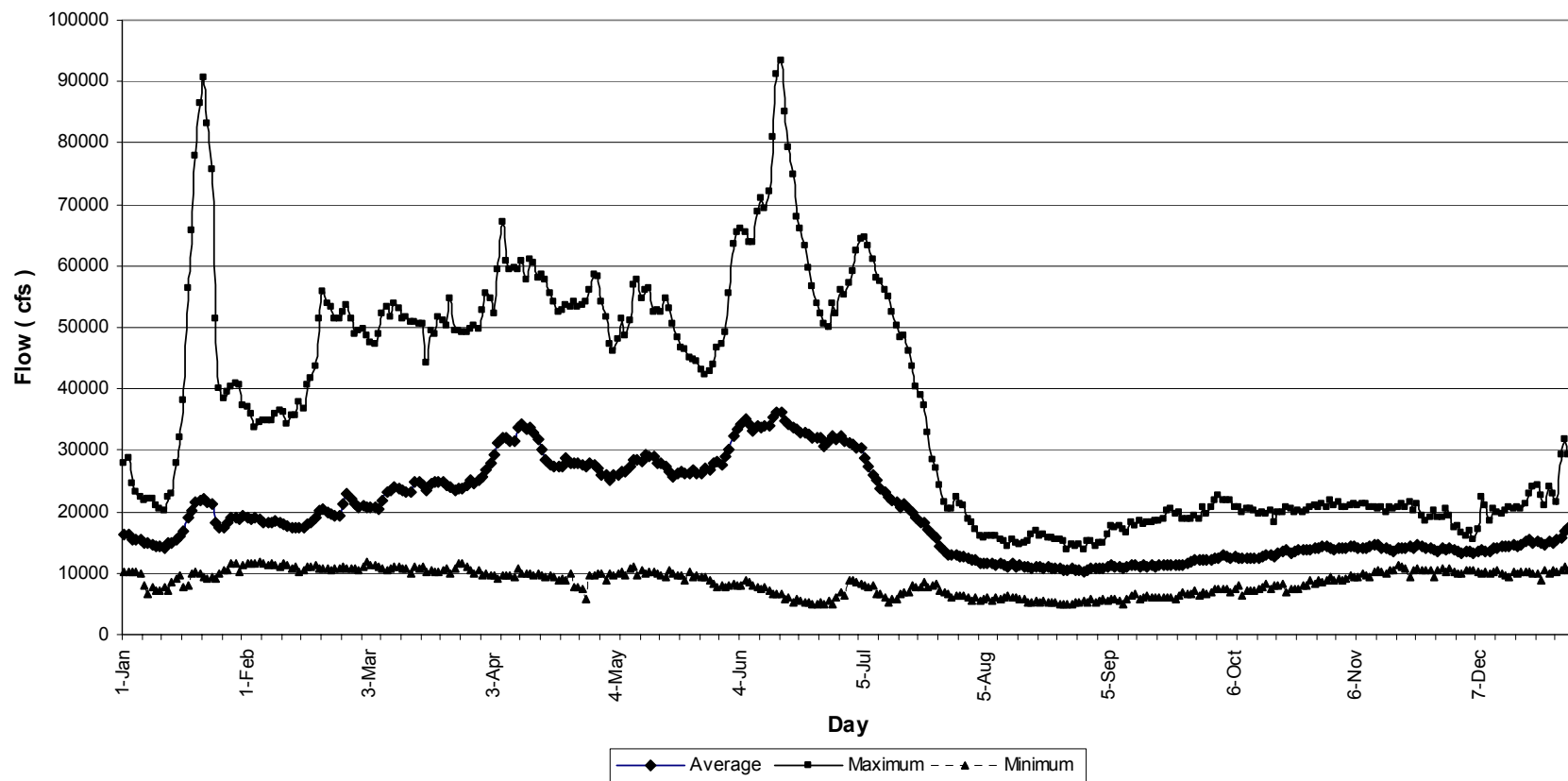
Flow at Hells Canyon Dam - Full Pool (1970 to 1979)



Flow at Hells Canyon Dam - Full Pool (1980 to 1989)



Flow at Hells Canyon Dam - Full Pool (1990 to 1999)



CHAPTER 4: PROBABLE IMPACTS OF WATER MANAGEMENT SCENARIOS ON NOXIOUS AND INVASIVE PLANTS ALONG RIPARIAN ZONES OF THE HELLS CANYON CORRIDOR

4.1. Introduction

It is noteworthy that the flora ‘Weeds of the West’ (Whitson et al. 1996) describes many of the common plants found along riparian corridors throughout the American west, including the Hells Canyon corridor. Riparian landscapes experience natural disturbances particularly associated with flood events but also more regularly the progressive sediment erosion and deposition that accompany moderate flows. ‘Weeds’ commonly refers to invasive exotic plants and these plants are generally well adapted to vigorously colonize disturbed areas. Since riparian zones face regular natural disturbance these zones are particularly prone to weed infestation.

Consistent with this general interpretation, the riparian zones along the Hells Canyon corridor support many exotic plants, including abundant weed species. About one-half (97) of the 196 vascular plant species identified during the field sampling described in Chapter 2 were exotic (introduced) plants (Appendix 3.1). The general distributions of the exotic plants varied longitudinally along the Hells Canyon corridor as discussed in Section 1.2.8., Chapter 1, of the present report. Upstream areas tended to have higher proportions of exotic plants whereas the Snake River reach below Hells Canyon Dam had the highest proportion of native plants and this was especially the case for woody riparian plants (Figure 2.53, Chapter 2.). These prominent patterns were previously noted by Holmstead (2001), who also discussed causes and contributions to these weed distributions.

4.2. Problem Plants

Noxious weeds constitute a subset of weeds and these noxious species are particularly undesirable. The designation of noxious weeds varies across states and even counties and is somewhat arbitrary. Noxious designation was historically based particularly on agricultural impact to either crops or livestock pastures but the term and concept should also apply more broadly to plants that seriously degrade natural ecosystems. To accommodate this broader consideration relative to riparian vegetation communities, Holmstead (2001) and Krichbaum (2000) considered designated noxious plants and also plants that are potentially severely invasive in assessments of problem species along the Hells Canyon corridor.

In the present study, 16 plant species identified in the field transects described in Chapter 2 are regionally designated as noxious plants and 4 other species are potentially severely invasive in riparian zones (Table 4.1.). These 20 problem plant species deserve additional consideration relative to the potential differences in distribution patterns across the two water management scenarios assessed in Chapter 3.

The analyses of scenario impacts relative to these problem plants should consider two aspects. *Dispersal* represents the capacity for propagule distribution. Many noxious and invasive plants invoke clonal dispersal of vegetative fragments in addition to seedling reproduction and both clonal and sexual (seedling) processes contribute to population expansion. *Proliferation* represents the capacity of the plant to become established, thrive, and locally expand. The HC_REM particularly addresses proliferation but the process of dispersal may be even more important relative to water management scenario impacts on riparian zones. This is particularly the case relative to invasive exotic perennials and especially invasive woody plants. For example, as discussed by Holmstead (2001) tamarisk is currently absent from the unimpounded Snake River reach below Hells Canyon Dam and the continued exclusion of this plant could provide an important consideration in reservoir management.

We grouped noxious and invasive plants by vegetation group in accordance with considerations outlined in Chapter 3 (Table 4.1.). This grouping is applicable to treatment by the HC_REM but other considerations are also important. Thus, problem species will be discussed by vegetation group and also with reference to other aspects that relate to particular species or subgroups.

This analysis is somewhat speculative since the autecological traits of many noxious and invasive plants are poorly understood (one exception being tamarisk). Since tamarisk has become an extensive problem species along rivers of the American southwest there have been a number of studies of its life history traits (partly reviewed in Chapter 3, Appendix 3.2). For the other species, the responses to water stage pattern and other characteristics can only be broadly deduced based on current distribution patterns.

Overlap with Prior Studies

The present study complemented two prior investigations that addressed the distributions and abundances of noxious and invasive species along the Hells Canyon corridor. Holmstead (2001) inventoried vegetation along the corridor with analyses at two spatial scales. Mapping of vegetation cover types within a corridor of 0.5 (above Hells Canyon Dam) or 0.25 mi (below Hells Canyon Dam) from the river or reservoir edge was based on air photo interpretation with field-verification. More detailed field sampling of each polygon type (plant assemblage/ community) was based on belt transects positioned within each polygon type. Polygons were sampled from upland and riparian zones with both a systematic random sampling strategy and more directed sampling strategy for both the upland and riparian zones (386 upland and 859 riparian transects, 1994 to 1999). The sampling was thus based on ecological units and investigated the different vegetation types that were mapped. Thus, Holmstead (2001) provides a comprehensive broad-scale spatial inventory of the riparian corridor and subsequently describes local plants and plant communities.

Krichbaum (2000) conducted a study that focused on rare plants and noxious weeds based on field sampling in 1998 and 1999. Krichbaum's sampling was spatially-based, with a 50 m wide, ¼ mile long segment selected randomly within each 1 mile segment of the corridor (405 survey units observed). Krichbaum (2000) assessed plants and local site conditions of each sample segment and applied ANCOVAs to detect patterns relating plant occurrences and site characteristics.

As described in Chapter 2 of the present report, our study involved the sampling of cross-sectional belt transects that extended perpendicularly from the reservoir or river edge. These cross-sections progressed through the sequence of ecological zones and elevational survey permitted the comparison of plant occurrences with historical and proposed water surface patterns. The sampling involved the random selection of one position from each one-mile segment of the study corridor and then subsequently 25 additional sampled positions to provide coverage of all fluvial geomorphic surfaces (185 total transects).

The three studies thus applied different sampling strategies as they had somewhat different objectives. Holmstead's (2001) study provided vegetation, natural feature and land-use inventories that enabled the classification of the overall landscape in 26 cover types. This permitted the quantitative description of landscapes of the river and reservoir corridor. Krichbaum's (2000) study specifically targeted noxious, invasive and rare plants and also analyzed site characteristics typical of their occurrences. Our study focused on the elevational distribution of plants along reservoir shorelines and riverbanks as this determination was essential for the hydrogeomorphic modeling of riparian vegetation.

All three studies include analyses of distributional patterns of the local noxious plants and all three also provide some interpretation regarding processes that underlie spatial patterns. Since the three studies were completed independently and by separate botanists, they provide replication with respect to inventory and interpretation. Collectively, the three studies also strengthen the basis for interpretation since each study reveals additional information as well as confirming spatial patterns. The following analyses focus on the results of the present study but also relate relevant results from prior studies. In the final discussion that closes this chapter, critical aspects relating to the different studies will be further discussed.

4.2.1. Upland Plants

The longitudinal distributions of the noxious and invasive upland plants are represented in Figure 4.1. These represent occurrences along the 185 transects of the present study with proportional occurrences and cover abundances following in Tables 4.2. and 4.3.

As a group, upland weedy species were broadly distributed along the elevational transects (Figure 4.2.). These weeds occurred at all elevations sampled along the Weiser reach of the Snake River. Those transects were typically limited in elevational extent since the upper end reached an agricultural field or other zone of severe human impact.

These upland weeds were abundant along the Brownlee Reservoir study reaches and were favored at higher elevations (Figure 4.2.). This is consistent with their assignment as upland species. These upland weeds were generally less abundant along the lower reservoir reaches (i.e., Oxbow and Hells Canyon Reservoirs). Along these reaches, upland weeds continued to be favored at higher elevations (Figure 4.2.).

These upland weeds generally occurred along the Snake River downstream of the Hells Canyon Dam but with the exception of St. Johns wort (HYPE) were generally less extensive and abundant along this river riparian zone than along the reservoir riparian zones (Figure 4.1., Tables 4.2. and 4.3.). Along the Snake River below Hells Canyon, these upland weeds occurred

at a range of elevations but, as was the case along the reservoirs, tended to be more common at upper elevations (Figure 4.2.).

Thus, upland noxious weeds were identified along the riparian zones of the present study but also typically extend upwards into upland habitats. Given their upland occurrence, this group of plants would typically be less affected by the proposed versus ROR scenarios than the other vegetation groups. However, dispersal can be substantially affected as some of these species display hydrochory, water-based dispersal of propagules.

Agropyron repens—Quackgrass (abbreviation AGRE)

Quackgrass was sparse in the riparian transects along the Hells Canyon corridor, occurring in only two quadrats of a single transect along the Powder Arm of Brownlee Reservoir (Figure 4.1., Tables 4.2. and 4.3.). Krichbaum (2000) also reported a sparse but more widespread occurrence in the upland zones. With occurrence in upland as well as facultative riparian zones and with its distribution is favored by various disturbances, the overall status of this noxious plant is not likely to be substantially impacted by either the proposed or ROR water management scenarios.

Conclusion: minimal difference across flow scenarios.

Cardaria draba—White Top/Hoary Cress (CADR)

Although listed as upland species, white top is an aggressive invader in some riparian zones. In addition to *Cardaria draba*, two other *Cardaria* species, *C. chalepensis* and *C. pubescens*, are closely related ‘white-top’s’ that are also common weeds across the western United States and differentiated only by morphological differences in seed capsules and fruits (Whitson et al. 1996). *Cardaria draba* occurred sparsely along the riparian transects of the present study, with two quadrats of one transect along each of the Powder River Arm of Brownlee Reservoir and the main Brownlee Reservoir (Figure 4.1., Tables 4.2. and 4.3.). Krichbaum (2000) reported more extensive occurrence in surveys, particularly in upland habitats.

Despite their relative common occurrence in upland habitats along the Weiser reach of the Snake River and the Brownlee Reservoir, *Cardaria draba* is sparse along the Snake River below Hells Canyon Dam (Krichbaum 2000). Consequently, future dispersal from the upstream reaches should be particularly considered. In this regard, the proposed scenario should continue to discourage downstream expansion from the populations occurring along the upstream portions of Brownlee Reservoir.

Conclusion: Proposed scenario should discourage downstream expansion of white tops.

Cirsium arvense—Canada Thistle (CIAR)

Canada thistle was restricted to the upstream reaches of the present study. It occurred along almost one-half of the riparian transects of the Weiser reach of the Snake River and one upstream transect along the headwater reach of Brownlee Reservoir as well as along two of the three transects along the Powder River Arm of the reservoir (Figure 4.1., Table 4.2.). This distribution is consistent with the inventory of Krichbaum (2000) who concluded that this noxious weed was primarily associated with agricultural and other disturbances and generally situated in upland

zones. This weed is thus impacted more by factors other than water management and might not differ substantially across the two management scenarios. Conversely, the lack of expansion downstream along Brownlee Reservoir suggests that this may currently serve as a barrier to downstream expansion and that impediment would continue with the proposed scenario.

Conclusion: probably minimal difference across flow scenarios.

Convolvulus arvensis—Field Morning-glory/Bindweed (COAR)

Along the riparian transects, field bindweed occurred along much of the Hells Canyon corridor with considerable abundance at many sites (Tables 4.2. and 4.3.). As with most weeds, it was most abundant along the Weiser reach of the Snake River and the headwater reach of Brownlee Reservoir and occurred along about one-quarter of the transects along those two reaches. It was then progressively less abundant along the main Brownlee, Oxbow and Hells Canyon reservoirs occurring in 13%, 6% and 4% of transects, respectively. It occurred in about 5% of the riparian transects along the Snake River below Hells Canyon. These distributions were generally consistent with the findings of Krichbaum (2000) who further concluded that field bindweed was associated with a number of disturbances such as trails and roads. With a broad distribution and extensive upland occurrence, it is not likely to be substantially affected by either the proposed or ROR water management scenarios.

Conclusion: minimal difference across flow scenarios.

Cynoglossum officinale—Houndstongue (CYOF)

Houndstongue was not common along the riparian transects of the present study except along the Oxbow Reservoir where it occurred in about 18% of the 17 transects (Figure 4.1., Tables 4.2. and 4.3.). In contrast to its scarcity in riparian zones, this noxious weed was abundant in upland zones; Krichbaum (2000) reported that it was the third most abundant noxious weed along the Hells Canyon corridor. Krichbaum (2000) concluded that it occurred in association with a range of disturbances, in which its burred seeds enabled dispersal by humans or other animals. Due to the upland occurrence and animal dispersal it would be impacted more by factors other than water management.

Conclusion: minimal difference across flow scenarios.

Euphorbia esula—Leafy Spurge (EUES)

Along the riparian transects leafy spurge was only found in two of the 15 riparian transects along the Weiser reach of the Snake River, upstream from the reservoirs (Figure 4.1., Tables 4.2. and 4.3.). This distribution is consistent with that of Krichbaum (2000) who found only two populations along the Weiser reach and a single population along Brownlee Reservoir.

Although listed as an upland species, leafy spurge is a dominant riparian weed along many streams in cooler, semi-arid regions such as Montana and southern Canada (Selleck et al. 1962). Along streams in these areas, leafy spurge has become a dominant plant, partly due to the production of stem sap alkaloids that discourage herbivory. Seeds and vegetative fragments (Raju et al. 1963) are dispersed along waterways and once established, the plant moves upward

from the riparian zone into transitional and upland habitats. Control strategies based on herbicides or grazing by sheep have not been successful, but biocontrol strategies particularly with herbivorous beetles have been successful (Brinkman et al. 1997).

Along the Hells Canyon corridor, leafy spurge is currently sparse and restricted to the upstream ends of Brownlee Reservoir. Since the plant is not currently profuse along the upstream zones, it is likely that regional environmental conditions may not be optimal for this invasive weed. Conversely, the weed could be relatively new to the region and populations may increase over time. Its dispersal has probably been impeded by the historical pattern of draw-down of Brownlee Reservoir. The continued annual filling and draw-down of Brownlee Reservoir with the proposed scenario would probably continue to discourage downstream dispersal.

Conclusion: Proposed scenario should discourage downstream dispersal.

Hypericum perforatum—Common St. Johns Wort (HYPE)

St. Johns wort was the most abundant noxious weed along the riparian transects through the Snake River reach downstream from Hells Canyon Dam (Figure 4.1., Tables 4.2. and 4.3.). It occurred in 24% of the riparian transects and produced 10% cover of the 73 quadrats in which it occurred. This abundance along the Snake River contrasted with reduced occurrence along the riparian transects in the lower reservoirs. It occurred in 18% of the transects located along Oxbow Reservoir and 8% of those along Hells Canyon Reservoir. Further extending this trend, this weed was absent from the riparian transects along the upstream study reaches of Brownlee Reservoir and the Weiser reach of the Snake River (Figure 4.1.). Krichbaum (2000) found similar patterns of distribution along the Hells Canyon corridor.

With this distribution, proliferation rather than dispersal would be the aspect of primary concern. As an upland plant, its proliferation at the upper end of the riparian zone would be expected to respond somewhat similarly to that of the facultative riparian perennial vegetation group. The HC_REM predicts minimal change in this vegetative group along the Snake River reach below Hells Canyon (Table 6.1., Chapter 6) and a similar conclusion would probably apply for this noxious weed.

Conclusion: minimal difference across flow scenarios.

Linaria genistifolia—Dalmation Toadflax (LIGE)

Dalmation toadflax was sparse along the riparian transects, occurring only at four quadrats along two transects near the upstream end of the main Brownlee Reservoir (Figure 4.1.). Krichbaum (2000) also reported scarce occurrence, primarily in upland zones. As a predominately upland weed, its potential expansion would be more dependent upon factors other than water management scenario.

Conclusion: no difference across flow scenarios.

Onopordum acanthium—Scotch thistle (ONAC)

Scotch thistle occurred occasionally along the riparian transects throughout the Hells Canyon study corridor (Figure 4.1., Table 4.2.). It was slightly more abundant along the Brownlee Reservoir occurring in 9% and 11% of the transects located in the headwater and main reservoir reaches. It occurred in only one of the 46 transects along the lower reservoirs and in 4 of the 93 transects along the Snake River below the Hells Canyon Dam. In contrast to its relative scarcity along riparian zones, Krichbaum (2000) reported a much more extensive occurrence in the upland zones along all reaches of the study corridor. In fact, it was the most abundant noxious weed inventoried. It is promoted by a range of disturbances, and with an upland distribution it presents another case in which water management would probably have little influence on its future distribution.

Conclusion: minimal difference across flow scenarios.

Taeniatherum caput-medusae—medusahead wildrye (TACA)

Medusahead wildrye occurred commonly along the riparian transects along the reservoir reaches but was very scarce along the Snake River reach downstream (Figure 4.1., Table 4.2.). It presented an unusual distributional pattern with abundant occurrence along the main Brownlee Reservoir and the Oxbow Reservoir (53% and 47% of transects) but sparse occurrence along the Hells Canyon Reservoir (16%) and absence in the headwater reach of Brownlee Reservoir (0%). This pattern is somewhat consistent with that reported by Krichbaum (2000), although that prior study did not report a breakdown by sub-reaches. Suited to upland landscapes, this noxious plant appears to be hindered by flow disturbance and is thus disfavored in riparian zones (Krichbaum 2000). As with most of the other upland weeds, it is unlikely that there would be substantial differences in the future distribution of medusahead wildrye across the water management scenarios.

Conclusion: no difference across flow scenarios.

Of these upland noxious weeds, it is likely that white-top and leafy spurge may particularly demand consideration. Both are severely invasive in riparian and transitional zones along other rivers in fairly similar ecoregions and it is thus likely that these plants might thrive along the Snake River below Hells Canyon Dam. Along the study corridor they are currently limited to the reservoir riparian zones and dispersal down to the Snake River reach below Hells Canyon Dam should thus be discouraged.

With regard to dispersal, the annual draw-down of Brownlee Reservoir with the proposed scenario might discourage progressive downstream expansion. Invading individuals of these perennial plants could establish in the draw-down zone where they would suffer from drought-stress with further draw-down and subsequent inundation that could destroy surviving plants.

Relative to proliferation, these upland noxious plants might be less responsive, but somewhat similarly affected as the facultative riparian perennial vegetation group modeled by HC_REM. That group of plants is slightly discouraged by the proposed scenario along Brownlee Reservoir and possibly the lower reservoir reaches, but generally similar under the two scenarios for the Snake River reach below Hells Canyon Dam (Table 6.1., Chapter 6). Thus, although HC_REM

predicts rather slight affects and extending into the upland landscapes, these upland noxious weeds would respond more to other disturbances factors and thus less dependent on water stage patterns than the riparian vegetation groups described in the following sections.

4.2.2. *Facultative Riparian Perennials*

These noxious and invasive plants are more dependent than upland species on the additional moisture provided in riparian zones. These plants will occur in both upland and riparian zones and are often most abundant in transitional areas linking these two zones (Figure 4.3.). The overall proliferation of these species would be more dependent upon river and reservoir regulation than that of the upland plants but this conclusion may not necessarily apply to dispersal vectors.

Conium maculatum—Poison hemlock (COMA)

Poison hemlock was abundant (47% of 15 transects) along the riparian transects of the Weiser reach of the Snake River, upstream from the reservoirs (Figure 4.1., Tables 4.2. and 4.3.). This noxious weed was absent from transects of all three Brownlee Reservoir reaches but occurred along the Oxbow (6%) and Hells Canyon (4%) reservoirs. Their occurrence along the main Oxbow Reservoir is notable since the four quadrats containing poison hemlock contained an average cover of 64%; the highest mean proportion of quadrat cover observed for a noxious or invasive plant in the present study (Figure 4.3.). Poison hemlock also occurred in 4% of the transects along the Snake River below Hells Canyon Dam (Figure 4.3.).

Lepidium latifolium—Perennial pepperweed (LELA)

Perennial pepperweed or ‘tall white-top’ was abundant along the Weiser reach of the Snake River and along all of the reservoirs of the Hells Canyon Corridor (Figure 4.1.). It was thus the second most abundant problem plant in the study (behind false indigo, Tables 4.2. and 4.3.). It occurred in 60% of the riparian transects along the Weiser reach and 55% of the transects in the Brownlee headwater reach (Table 4.2.). It was less abundant along the main Brownlee Reservoir reach (13%), but again was abundant along the three sequential lower reservoir reaches (53%, 50%, 36%, Table 4.2.). Perennial pepperweed was not observed downstream of Hells Canyon Dam and this absence is consistent with the distribution patterns determined by Krichbaum (2000).

Both poison hemlock and perennial pepperweed would likely respond to reservoir management similar to other facultative riparian perennials. Correspondingly, HC_REM predicts slightly less favorable conditions with the proposed scenario for Brownlee Reservoir and possibly for the lower reservoirs but little change along the Snake River below Hells Canyon Dam. These predicted impacts are relatively minor and these two noxious weeds may not substantially differ across the two water management scenarios.

Conclusion: minimal difference across flow scenarios for these two noxious species.

Eleagnus angustifolia—Russian olive (ELAN)

A facultative riparian perennial, Russian olive provides a case of a potentially seriously invasive exotic plant that is not locally designated as noxious. In contrast to many of the prior discussed noxious weeds, the life history of Russian olive is better understood relative to the influence of water regulation (Shafroth et al. 1995, Lesica and Miles 1999, 2001). Dispersal is an important attribute, as its large seeds are widely dispersed by birds and other animals. During animal dispersal, the hard seed coats may be scarified, reducing coat-imposed seed dormancy that would otherwise require after-ripening and produce delayed and variable germination (Shafroth et al. 1995). In addition, the common occurrence of saplings in bands along many stream banks throughout the West suggests water-borne dispersal may also be important. Independent of this dispersal mechanism, their seeds require moist conditions for germination, establishment and survival. Consequently, Russian olive is particularly invasive in riparian zones.

Russian olive was limited along the Hells Canyon corridor; generally restricted to the Weiser reach of the Snake River and areas upstream of the Brownlee Reservoir (Figure 4.1., Table 4.2.). This tree had been deliberately planted in agricultural areas adjacent to the Weiser reach and probably provided the principal source of propagules for this invasive exotic.

Russian olive also occurred on three quadrats in one transect along the main Oxbow Reservoir (Figure 4.1., Table 4.3.). Trees had also been planted in the parks and developed areas along the lower reservoirs, which would provide additional seed sources for this invasive tree (Table 4.2.).

In elevational distribution, Russian olive generally occurred at the full pool level of reservoirs up to about 3 m above full pool (Figure 4.3.). The tree occurred slightly below the mean annual water level along the Weiser reach of the Snake River (Figure 4.3.). This distribution appears to reflect the water requirements of the seedlings and saplings in addition to possible water-borne seed dispersal.

It is likely that the regular draw-down of Brownlee Reservoir has hindered the downstream expansion of this invasive tree. It is further predicted that the draw-down pattern associated with the proposed scenario would continue to discourage downstream expansion of this exotic species. However, dispersal from other source areas along the lower reservoirs would not be hindered by either the proposed or ROR scenarios. To minimize the future seed source along the lower reservoirs, deliberate ornamental planting of this exotic species, in areas such as the town of Oxbow and in parks along the lower reservoirs should be strongly discouraged.

Conclusion: Proposed scenario should discourage downstream dispersal through Brownlee Reservoir.

4.2.3. Obligate Riparian Perennials

This vegetation group is critical relative to future riparian conditions along the Hells Canyon corridor. Obligate riparian plants are more restricted to riparian zones than the facultative riparian plants. They generally have greater water requirements and lower elevational occurrences in the riparian zones than facultative riparian plants.

Cyperus esculentus—Yellow nut sedge (CYES)

Yellow nut sedge was observed in 40% of the riparian transects along the Weiser reach of the Snake River and 36% of the riparian transects along the headwater reach of Brownlee Reservoir (Figure 4.1., Table 4.2.). This sedge occurred in 3% of the riparian transects of the main Brownlee Reservoir but not along riparian transects further downstream. This observed distribution contrasts somewhat with that of Krichbaum (2000) who reported this species as primarily occurring along the Snake River downstream of Hells Canyon Dam. In both surveys, the plant was a minor weed and it is not anticipated to represent as serious a problem as some of the other noxious and invasive species. The HC_REM predicts rather slight differences across the two scenarios in the obligate riparian perennial vegetation group; a prediction that appears applicable to the yellow nut sedge.

Conclusion: minimal difference across flow scenarios.

Amorpha fruticosa—False Indigo (AMFR)

This exotic woody plant generally occurs as a small shrub and was abundant along the Hells Canyon reservoirs. It did not occur along the riparian transects downstream of Hells Canyon Dam but was recognized during the float trips along this reach. Krichbaum (2000) reported its occurrence in 8% of the 0.5 mile segments he inventoried along the Hells Canyon reach of the Snake River.

Along the riparian transects of the present study, false indigo was the most abundant problem species (Figure 4.1., Tables 4.2. and 4.3.). It occurred extensively along the Weiser reach of the Snake River (27% of 15 transects) and through the headwaters reach of Brownlee Reservoir (36% of 11 transects) and part-way down the main reservoir (24% of 38 transects) (Figure 4.1.). After a gap in distribution along the lower portion of Brownlee Reservoir, false indigo was again very common along the lower reservoirs where it occurred in about one-half of the 46 transects along those reaches. It was also extensive in abundance providing about 40% cover in the quadrats in which it occurred throughout the study area (Table 4.3.).

Along these transects, false indigo occurred at elevations consistent with other obligate riparian perennials (Figure 4.4.); from 0.5 m below to about 2 to 3 m above full pool. Along the Weiser reach of the Snake River, it generally occurred below the mean annual water level. This limited elevational distribution probably reflects a combination of its water requirements for establishment and survival and the consequences of hydrochory, water-based propagule dispersal.

False indigo is abundant upstream of the Hells Canyon complex, including extensive occurrence along the Weiser River, just upstream of the project. Due to its prominence along the reservoirs and capacity for future expansion along the Snake River reach below Hells Canyon Dam, it was the focus of more comprehensive life history investigation associated with the determination of the vegetation groups (discussed in Chapter 3). Detailed aspects of its life history are presented in the Life History report found in Appendix 3.2.

False indigo is native to the mid-western and southeastern United States (Lapin and Nothnagle 1995) and has become widely distributed across the country (Palmer 1931). It can dominate riparian areas due to the combination of seedling and clonal expansion.

It is a legume and generally occurs as a shrub or small tree with clumped stems up to 4 to 5 m tall (Lapin and Nothnagle 1995). An impermeable seed coat imposes seed dormancy that results in delayed natural germination (Lapin and Nothnagle 1995). This shrub is also extensively clonal, with potential for dispersal from stem and root fragments, particularly following floods (Lapin and Nothnagle 1995).

Since false indigo is already extensive along the lower reservoirs, the draw-down of Brownlee Reservoir has not prevented downstream expansion of this species to the Hells Canyon reach of the Snake River. Although it did not occur in our study transects below Hells Canyon Dam, Krichbaum (2000) reported that it was present, though relatively sparse, in this lowermost reach. Thus, downstream dispersal is not as critical an issue as it is for those noxious or invasive plants that are currently restricted to the Weiser and Brownlee headwater reaches.

The HC_REM predicts only slight differences for the obligate riparian perennials and this appears applicable to false indigo. Independent of the water management scenario it is likely that this invasive shrub will continue to proliferate through much of the Hells Canyon corridor.

Conclusion: minimal difference across flow scenarios.

Phalaris arundinacea—Reed canarygrass (PHAR)

Reed canarygrass, a perennial grass, is the only native plant considered in this discussion of problem species (although some researchers consider reed canarygrass as an introduced plant, Merigliano and Lesica (1998) present information favoring a native status in the western United States). It is an invasive species that can flourish in disturbed riparian areas causing other native plants to suffer (Merigliano and Lesica 1998, Morrison and Molofsky 1999). At this time, the causes of its proliferation are not fully understood.

Reed canarygrass was abundant along the upstream reaches of the present study and then sparse downstream (Figure 4.1., Table 4.2.). It was particularly abundant along the Weiser reach of the Snake River and along the Brownlee headwater and Powder Arm reaches of Brownlee Reservoir where it occurred in 60%, 36% and 67% of the riparian transects, respectively. It was less abundant through the main Brownlee Reservoir (3%) and sparse along the lower reservoirs, occurring in 8% of the Hells Canyon Reservoir transects.

In elevational distribution, reed canarygrass was situated at or slightly below the full pool levels of the reservoirs and the mean annual water level of the Weiser reach (Figure 4.5.). Its only occurrence along the Snake River downstream from Hells Canyon was at an unusual elevation, well above the zone typical for obligate riparian plants, which reflects access to moisture from an alternate source than the river.

As an obligate perennial, HC_REM predicts rather slight differences across the water management scenarios. This is probably equally applicable to reed canarygrass.

Conclusion: minimal difference across flow scenarios.

Tamarix ramosissima* and *T. parviflora—salt cedar complex (TARA)

Deliberately introduced into the American west as an ornamental and also planted for stream bank stabilization, these Eurasian (*T. ramosissima*) and European (*T. parviflora*) perennial shrubs have had devastating impacts along streams, particularly in the American southwest. The invasion of this exotic plant provides one of the most dominant ecological impacts on western riparian ecosystems.

Along the Hells Canyon corridor, following its extension from the Weiser reach of the Snake River, salt cedar is currently the most common riparian perennial along the headwater reach of Brownlee Reservoir (Table 3.1.A., Chapter 3). In contrast, it did not occur along transects of the main Brownlee Reservoir or downstream along the lower reservoirs or Snake River below the Hells Canyon Dam (Tables 4.2. and 4.3.). This distributional restriction is generally consistent with the sampling by Krichbaum (2000), who found a few isolated populations along Brownlee Reservoir and the observations of Holmstead (2001). Holmstead (2001) along with tree coring by our study team further suggests that its occurrence along the Brownlee Headwater reach is relatively recent (10–15 years).

Salt cedar was abundant in the regions where it was found (Tables 4.2. and 4.3.). It occurred along one-third of the 15 transects along the Weiser reach of the Snake River and almost three-quarters of the 11 transects along the headwater reach of the Brownlee Reservoir. It provided about one-third cover in the 54 quadrats that it occupied.

Seedlings of woody plants were also inventoried along the riparian transects and salt cedar seedlings (TARAS) were the most abundant woody plant seedlings observed in the present study (Tables 4.2. and 4.3.). Seedlings occurred in 60% of the riparian transects of the Weiser reach and about one-quarter of the transects along the Brownlee headwater reach.

In elevational pattern, salt cedar occurred slightly below the mean annual water level along the Weiser reach of the Snake River (Figure 4.6.). Along the headwater reach of the Brownlee Reservoir it covered a much broader elevational zone, occurring from 3 m below to 3.5 m above the full pool elevation with relatively similar proportional abundance across that elevational band (Figure 4.6.). This elevational distribution demonstrates the breadth of potential adaptation by this invasive plant. In the zones below full pool, the shrub would be exposed to periodic inundation while in the zone well above full pool, the plant would occur at the upper end of the zone of riparian plants.

Seedlings were more restricted in elevational occurrence but their location would vary across years. The observed seedlings occurred at the upper end of the zone of mature salt cedar shrubs/trees along the Weiser reach of the Snake River but at the lower end of zone of mature plants along the headwater reach of the Brownlee Reservoir (Figure 4.6.). Since sampling occurred in late summer, it is likely that earlier in the season broader zones of seedlings would have been observed. The abundance of salt cedar seedlings confirmed the active recruitment of seedlings by this invasive plant.

While the extensive occurrence of salt cedar along the Weiser reach and the Brownlee headwater reach invokes concern over future conditions, the longitudinal distribution provides some cause for optimism regarding the prevention of future expansion. Salt cedar was abundant along transects at the upstream end of the Brownlee headwaters reach, but absent along the transects that were furthest downstream (Figure 4.1.). Subsequently, no salt cedar seedlings or shrubs were observed at any transects through the main Brownlee reservoir or along the lower reservoirs or the Snake River downstream from the Hells Canyon Dam. It thus appears that either (1) the main reach of Brownlee Reservoir is acting as an effective barrier to downstream extension and passage, or (2) the progressive downstream expansion is just approaching the main Brownlee Reservoir. To assess these two possibilities and to further consider the probable impacts of the two water management scenarios, it is appropriate to consider the adaptive life history of this invasive plant.

The plant is a loosely branched shrub or small tree that grows 1 to 6 m tall with a typical life span of 75 to 100 years (Horton 1977, Devitt et al. 1997). Although taxonomy and systematics are still being evaluated, since its first introduction to the United States as an ornamental in the 1800s, a total of eight species have been introduced as ornamentals and wind breaks. Three of these are considered naturalized along streams or wet areas of semiarid regions of the western United States (Bensen and Darrow 1981, Di Tomaso 1998).

Salt cedar continues to spread north into Montana and Canada (DeLoach 1989, Swenson et al. 1982, Lesica and Miles 2001) and south to northeastern Mexico (DeLoach 1989). It has become naturalized and is the dominant species along the middle and lower portions of the Colorado River drainage (Baum 1967). It has replaced up to 90% of lower Colorado River riparian communities that were typically dominated by cottonwoods and willows (Crins 1989).

Through the nineteenth century, salt cedar was considered to have a positive effect on riparian ecosystems since it provided a stabilizing effect on lakeside and stream bank substrates (Goldsmith and Smart 1982). With an extensive root system, this tree is more stable and resistant to erosion than many native riparian trees and shrubs (Di Tomaso 1998). Further, as an attractive ornamental with showy white or pink flowers (Di Tomaso 1998) it was and continues to be deliberately propagated and sold for landscape plantings.

It is now generally considered an undesirable tree since it provides poor wildlife habitat (Shrader 1977). Along many southwestern streams it has become established in monotypic stands with diminished vegetation diversity and structure that has resulted in the loss of many vertebrate species, particularly birds (Anderson et al. 1977, Cohan et al. 1978, Gladwin and Roelle 1998). It has also lead to the elimination of native riparian plants such as cottonwoods and willows (Ohmart and Anderson 1982, Busch and Smith 1995).

Its root characteristics are relevant to water-response modeling. During the first 4 weeks of seedling development, root growth is slow and seedlings are particularly vulnerable to desiccation (Kerpez and Smith 1987). This seedling root growth is slower than some native riparian species and provides an opportunity for management (Everitt 1980). However, while initial root growth is slow, tap roots can subsequently reach depths of 5 meters or even much deeper (Baum 1978, Brotherson and Field 1987).

Salt cedar is a facultative phreatophyte and thus can draw moisture from the saturated water table in riparian areas and can also extract soil moisture from less saturated soils in areas with deeper water tables (Everitt 1980, Busch et al. 1992, Cleverly et al. 1997). Thus, once established, salt cedar can thrive in the absence of saturated surface substrates (Brotherson and Field 1987). However, it is favored in riparian areas with an accessible water table and dense stands typically occur where water tables are 1.5 to 6 m below the surface (Horton and Campbell 1974, Kerpez and Smith 1987, Sala et al. 1996).

Unlike most obligate riparian plants, salt cedar is very drought tolerant. This permits established plants to tolerate watercourse desiccation and long-term drought (Blackburn et al. 1982, Devitt et al. 1997). Physiologically, it survives severe drought by transpiring earlier in the day and abscising leaves to reduce transpiration (Horton and Campbell 1974).

In addition to substantial drought-tolerance, mature plants are reasonably flood tolerant, being able to survive complete submergence for up to 70 days (Warren and Turner 1975, Brotherson and Field 1987, Kerpez and Smith 1987). Adventitious roots develop readily from submerged or buried salt cedar stems (Everitt 1980, Kerpez and Smith 1987). Fortunately, seedlings are less flood-tolerant (Horton et al. 1960). First year salt cedar seedlings do not survive well after autumn flooding but plants can survive more prolonged spring flooding in their second year (Gladwin and Roelle 1998). Although seedlings can survive submergence for a few weeks, they are easily uprooted even by a weak current for several months after germination (Kerpez and Smith 1987).

With respect to sexual reproduction, salt cedar displays a short juvenile phase, and can reach reproductive maturity in the first year (Ohmart and Anderson 1982, Neill 1985). Mature plants can flower throughout the entire growing season from April to October at lower elevations (Everitt 1980) and seeds are produced from mid-July to October in Colorado (Gladwin and Roelle 1998). Thus, salt cedar seeds are released later in the growing season and over a longer period than many other native woody plants of the southwestern United States (Reynolds and Alexander 1974, Schreiner 1974, Warren and Turner 1975). Also in contrast to the native willows and other native woody obligate riparian plants, some salt cedar seeds produced late in the growing season can retain viability until the next spring (Merkel and Hopkins 1957, Horton et al. 1960).

Salt cedar is a prolific seed producer, with an individual producing about a half-million seeds annually (Di Tomaso 1998). Seeds are small and light (0.1 mg) and tufted for wind and water dispersal (Brotherson and Field 1987, Sisneros 1991). Like willows, salt cedar seeds germinate rapidly, often within 24 hrs after imbibition (Kerpez and Smith 1987). Seeds have high initial viability and will remain vigorously viable under normal conditions for about 5 weeks (Everitt 1980). Seeds will germinate rapidly, but new seedlings require wet soil for several weeks (Horton 1977). Seedling establishment also requires at least 4 to 6 weeks without subsequent inundation (Shrader 1977, Kerpez and Smith 1987).

Salt cedar is also extensively clonal with capacity for resprouting following fire (Busch 1995) and flood disturbance. Vegetative fragments have considerable viability and this enables dispersive, clonal recruitment that compliments seedling establishment.

This expanded discussion of salt cedar is particularly relevant to the current and prospective situation along the Snake River. The regional climate through Hells Canyon is favorable for this exotic shrub since salt cedar thrives in the Brownlee Headwater reach and also downstream of Hells Canyon along the lower Snake River. It is thus likely that it would thrive along the Snake River below the Hells Canyon Dam, if introduced.

Consequently, a major priority with respect to riparian resource management would be to prevent the downstream expansion of salt cedar populations. The life history traits reveal that seedling recruitment is a vulnerable phase that would provide a suitable management target. The historical practice of draw-down of the Brownlee Reservoir has probably provided a barrier to downstream dispersal since the reservoir draw-down would be occurring during the late summer and early autumn period of seed release. Seeds would germinate at moist elevations well below full pool but continued draw-down would impose lethal drought stress. Seedlings that survive the draw-down would subsequently be inundated, providing another lethal stress to the vulnerable seedlings.

The plant is also dispersed through vegetative propagules but these appear to provide a minor mode of reproduction. As with the seedlings, clonal saplings established below full pool would not tolerate subsequent inundation. Clonal saplings might occasionally establish at or above full pool and these would have greater survival prospects. Salt cedar may gradually expand downstream along the full pool rim of Brownlee Reservoir (particularly along alluvial fans of side-tributaries) and these might eventually provide a source for seeds that would pass down to the lower reservoirs where recruitment would be more favorable. With this prospective sequence, the delay of expansion down Brownlee Reservoir is essential to retard the expansion of this invasive shrub towards the Snake River reach below Hells Canyon Dam.

This prior discussion focuses primarily on downstream dispersal and this is appropriate for natural processes associated with hydrochory (water-based dispersal). However, salt cedar also occurs downstream of the Hells Canyon corridor and along many other rivers and reservoirs across western North America. Upstream passage of propagules should be rare but not impossible. Such dispersal could result from transport by jet-boats traveling up-river and also by boat-trailers launching boats at Pittsburgh Landing. Both boats and trailers can provide dispersal vectors. For example, the dispersal of salt cedar by recreational boats and trailers is probably one process that has permitted salt cedar invasion along Fort Peck Reservoir and other reservoirs in Montana and elsewhere (Derald Smith and Cheryl Pearce, personal communication). Control of this transport vector would rely on educational programs to inform recreational boaters of this threat and the need to clean vegetation from boats and trailers.

With regard to the longer-term future prediction, it is likely that salt cedar will eventually enter the Snake River reach. It is also likely that bio-control insects will become established along the southwestern rivers and the experience from those systems may prevent the collapse of the native riparian communities along the Snake River, as occurred along the lower Colorado River and many other southwestern streams.

Conclusion: Proposed scenario should discourage downstream dispersal.

Of all of the probable impacts addressed in the present report, the prevention of encroachment of salt cedar into the natural riparian zone along the Snake River downstream from the Hells Canyon Dam may be the most ecologically significant. As a result, IPC should actively engage in programs focused on the control of salt cedar in the Hells Canyon Corridor.

4.2.4. Hydrophytes

Lythrum salicaria—purple loosestrife (LYSA)

Purple loosestrife was abundant along the riparian transects in the upstream reaches of the present study (Figure 4.1.). It occurred in two-thirds of the 15 transects along the Weiser reach of the Snake River almost one-half of the transects along the headwater reach of the Brownlee Reservoir (Table 4.2.). This distribution differs somewhat from the report of Krichbaum (2000), who found this weed to be less abundant along the headwaters reaches and similarly sparse but present downstream along the Oxbow and Hells Canyon reservoirs.

Along the riparian transects purple loosestrife was restricted to lower elevations than the hydrophytic species upon which HC_REM was developed (for example, Figure 3.5.). Along the headwater reach of Brownlee Reservoir, it occurred from 1 to 2.5 m below full pool, unlike the modeled hydrophytes that extended upwards to about 1 m above full pool (Figure 4.7.).

As a hydrophyte, this noxious weed is dependent upon a wetter environment than other riparian vegetation groups. Its lower occurrence along the riparian transects indicates that it requires even wetter environments than the modeled hydrophytes. The HC_REM predicts more favorable conditions for hydrophytes with the proposed scenario due to a downward extension of these zones along the Brownlee Reservoir reaches and also along the Snake River reach below Hells Canyon (Table 6.1.). However, the current lack of purple loosestrife along the main Brownlee Reservoir might indicate lesser drought-tolerance than plants used in HC_REM modeling of the hydrophyte vegetation group (Figure 3.8.). Thus, in contrast to the HC_REM prediction for other hydrophytes, the current lack of purple loosestrife along the main Brownlee Reservoir suggests an intolerance to reservoir draw-down. Thus, the proposed scenario might continue to impede this noxious plant. However, given the limited occurrence of this species in the present study, this analysis is somewhat speculative.

Conclusion: insufficient information to assess differences across flow scenarios.

4.2.5. Ruderal Annuals

The HC_REM analysis described in Chapter 3 predicts that the greatest differences among vegetation groups would occur for the ruderal annuals along Brownlee Reservoir. The model predicts 2- to 5-fold increases in the occurrence of this vegetation group due to the exposures of barren substrates along the reservoir draw-down zone (Table 6.1., Chapter 6). It is further likely that some exotic ruderal annuals will increase in abundance along the Brownlee Reservoir with the proposed scenario. Their increased abundance along this upstream reservoir would also increase the propagule source that might result in further downstream expansion of ruderal annuals.

Ambrosia artemisiifolia—common ragweed (AMAR)

Along transects of the present study, common ragweed was most common along the lower reservoirs, occurring in 4% to 25% of riparian transects (Table 4.2.). The plant was sparse along Brownlee Reservoir but moderate in abundance along the Snake River below Hells Canyon Dam occurring in 17 quadrats of 6 transects along the reach (Tables 4.2. and 4.3.). This distribution is generally consistent with that reported by Krichbaum (2000) except for slightly decreased abundance in Krichbaum’s survey for the lower Snake River reach.

The minimal occurrence along Brownlee Reservoir and increased abundance along Oxbow and Hells Canyon reservoirs suggests that although this plant is a ruderal annual, it benefits from the more stable water level of the lower reservoirs. Thus, in contrast to the general prediction of HC_REM for ruderal annuals, it is likely that this noxious weed would increase along Brownlee Reservoir with the ROR rather than the proposed scenario. It is currently a fairly sparse noxious weed along the Hells Canyon corridor and it is likely that the overall differences across the two scenarios would be minor relative to this plant.

Conclusion: minimal difference across flow scenarios.

Tribulus terrestris—puncture vine

Along the riparian study transects of the present study, puncture vine was abundant along the Brownlee Reservoir with extensive occurrence along the headwater reach (46% of transects) and also substantial occurrence along the main Brownlee Reservoir (16% of transects) (Table 4.2., Figure 4.8.). This distribution is generally consistent with the distribution reported by Krichbaum (2000), although he also found it to be abundant along the Oxbow and Hells Canyon reservoirs in higher elevational zones associated with road and recreational disturbance. This weed was very sparse along the Snake River reach downstream from the Hells Canyon Dam, occurring in only 1 of the 93 riparian transects.

The elevational distribution of this puncture vine is consistent with the HC_REM prediction for ruderal annuals (Figure 4.8.). It thus extends down through the draw-down zone along Brownlee Reservoir, both in the headwater reach and along the main reservoir. With this distribution, it would be favored by the proposed scenario over the ROR scenario. It is likely that as it proliferated along the Brownlee Reservoir, this zone would provide an increased source of propagules for subsequent downstream expansion.

Conclusion: increased occurrence and expansion with the proposed scenario.

4.3. Conclusions Regarding Probable Impacts of Flow Scenarios on Noxious and Invasive Plants

Following from these analyses of twenty noxious and invasive species, Table 4.4. provides a summary of predicted differences across the two water management scenarios. As indicated, the analysis based on a combination of HC_REM analysis and life history consideration, predicts that fifteen problem species would be similarly affected across the two water management

scenarios. One ruderal annual species, puncture vine, is predicted to increase in abundance with the proposed versus ROR scenario. Four perennial species, including white-top, leafy spurge, salt cedar and possibly Russian olive would be substantially reduced with the proposed scenario since the draw-down of Brownlee Reservoir would continue to impede their downstream expansion. The dispersal barrier imposed by the draw-down pattern of Brownlee Reservoir is anticipated to provide a substantial ecological benefit of the proposed scenario relative to the ROR scenario.

Consistent with the analyses of the current study, Holmstead (2001) also recognized the abundance of exotic plants along the Weiser Reach of the Snake River and along the headwaters of Brownlee Reservoir (see Holmstead (2001) text section, 'Exotic Weeds, pp. 44–47). Holmstead (2001, Table 12.) lists 16 weedy species that are generally restricted to these upstream reaches, including trees, shrubs, forbs and grasses. This list includes some of the problem plants analyzed in our study and in addition, the current distribution of noxious species such as Canada thistle, poison hemlock, perennial pepperweed and purple loosestrife suggests that these plants have been limited in downstream expansion by the presence and historic operation of Brownlee Reservoir.

Krichbaum (2000) discussed the prominence of weeds in all of the landscapes of the Hells Canyon corridor and points out that a number of factors and human impacts contribute to the proliferation of problem plants. Krichbaum (2000) recognizes the dispersal of seeds and vegetative fragments of many weeds by flowing water as a factor contributing to their success and expansion. Consistent with our study and the analysis of Holmstead (2001), Krichbaum (2000) found that 13 of the 17 weed species that occurred in 5% or more of the sampled units were more abundant along Brownlee Reservoir than along the Snake River downstream of Hells Canyon Dam.

Based on their current distribution and these other considerations, it is likely that considerably more than four noxious species have been historically restricted by the Hells Canyon reservoir complex; particularly by the draw-down of Brownlee Reservoir. In the short-term, the continuing draw-down that would occur with the proposed scenario would continue to hinder downstream expansion of about four to ten noxious weeds (as well as ten or more other exotic plants). However, HC_REM does not analyze aspects related to dispersive introduction of exotic plants and there are other relevant aspects related to the autecology of these noxious weeds that are not fully understood. We thus consider that our present HC_REM-based assessment underestimates the limitation of downstream expansion of problem plants that would occur under the proposed versus the ROR scenario.

Table 4.1. Noxious or invasive plant species that occur along the reservoir and river reaches.

| Vegetation Group | Species Scientific Name | Species Abbrev. | Common Name | Vegetation Class | Native or Exotic | Noxious or Invasive | Weiser & Reservoir Reaches | Snake River Reach ² |
|------------------------|---|-----------------|-------------------------|------------------|------------------|---------------------|----------------------------|--------------------------------|
| Upland | <i>Agropyron repens</i> | AGRE | quackgrass | PG | Exo | Nox | x | |
| Annuals and Perennials | <i>Cardaria draba</i> | CADR | white-top / hoary cress | PH | Exo | Nox | x | |
| | <i>Cirsium arvense</i> | CIAR | Canada thistle | PH | Exo | Nox | x | x |
| | <i>Convolvulus arvensis</i> | COAR | field morning-glory | PH | Exo | Nox | x | x |
| | <i>Cynoglossum officinale</i> | CYOF | houndstongue | BH | Exo | Nox | x | x |
| | <i>Euphorbia esula</i> | EUES | leafy spurge | PH | Exo | Nox | x | |
| | <i>Hypericum perforatum</i> | HYPE | common St. Johns Wort | PH | Exo | Nox | x | x |
| | <i>Linaria genistifolia</i> | LIGE | dalmation toadflax | PH | Exo | Nox | x | |
| | <i>Onopordum acanthium</i> | ONAC | Scotch thistle | BH | Exo | Nox | x | x |
| | <i>Taeniatherum caput-medusae</i> | TACA | medusahead wildrye | AG | Exo | Nox | x | x |
| Facultative | <i>Conium maculatum</i> | COMA | poison hemlock | BH | Exo | Nox | x | x |
| Riparian | <i>Lepidium latifolium</i> | LELA | perennial pepperweed | PH | Exo | Nox | x | x |
| Perennials | <i>Elaeagnus angustifolia</i> | ELAN | Russian-olive | WT | Exo | Inv | x | |
| Obligate | <i>Cyperus esculentus</i> | CYES | yellow nut sedge | PH | Exo | Nox | x | x |
| Riparian | <i>Amorpha fruticosa</i> | AMFR | false indigo | WT | Exo | Inv | x | |
| Perennials | <i>Phalaris arundinacea</i> | PHAR | reed canarygrass | PG | Nat | Inv | x | x |
| | <i>Tamarix ramosissima + parviflora</i> | TARA | salt cedar complex | WT | Exo | Inv | x | x |
| Hydrophytes | <i>Lythrum salicaria</i> | LYSA | purple loosestrife | PH | Exo | Nox | x | x |
| Ruderal | <i>Ambrosia artemisiifolia</i> | AMAR | common ragweed | AH | Exo | Nox | x | x |
| Annuals | <i>Tribulis terrestris</i> | TRTE | puncture vine | AH | Exo | Nox | x | X |

Vegetation Class abbreviations: A = Annual, B = Biennial, P = Perennial, G = Grass, H = Herb, W = Woody, T = Tree, S = Shrub

² river reach below Hells Canyon Dam

Table 4.2. Proportion (%) of riparian transects per reach where noxious or invasive plant species occur.

| Vegetation Group | Species Scientific Name | Species Abbrev. | Weiser | Brownlee Reservoir | | | Lower Reservoir Reaches | | | Snake River |
|------------------------|---|-------------------------|--------|--------------------|------|------|-------------------------|------|------|-------------|
| | | | (WR) | (BH) | (BP) | (BM) | (OM) | (OB) | (HM) | (SN) |
| Upland | <i>Agropyron repens</i> | AGRE | | | 33.3 | | | | | |
| Annuals and Perennials | <i>Cardaria draba</i> | CADR | | | 33.3 | 2.6 | | | | |
| | <i>Cirsium arvense</i> | CIAR | 46.7 | 9.1 | 66.7 | | | | | |
| | <i>Convolvulus arvensis</i> | COAR | 26.7 | 27.3 | | 13.2 | 5.9 | 4.0 | 5.4 | |
| | <i>Cynoglossum officinale</i> | CYOF | | | | 2.6 | 17.6 | | 1.1 | |
| | <i>Euphorbia esula</i> | EUES | 13.3 | | | | | | | |
| | <i>Hypericum perforatum</i> | HYPE | | | | | 17.6 | 8.0 | 23.7 | |
| | <i>Linaria genistifolia</i> | LIGE | | | | 5.3 | | | | |
| | <i>Onopordum acanthium</i> | ONAC | | 9.1 | | 10.5 | | 4.0 | 4.3 | |
| | <i>Taeniatherum caput-medusae</i> | TACA | 6.7 | | 33.3 | 47.4 | 52.9 | 50.0 | 16.0 | 1.1 |
| | Facultative | <i>Conium maculatum</i> | COMA | 46.7 | | | | 5.9 | 4.0 | 4.3 |
| Riparian | <i>Lepidium latifolium</i> | LELA | 60.0 | 54.5 | | 13.2 | 52.9 | 25.0 | 12.0 | |
| Perennials | <i>Elaeagnus angustifolia</i> | ELAN | 40.0 | 9.1 | | 2.6 | 5.9 | | | |
| Obligate | <i>Cyperus esculentus</i> | CYES | 40.0 | 36.4 | | 2.6 | | | | |
| Riparian | <i>Amorpha fruticosa</i> | AMFR | 26.7 | 36.4 | | 23.7 | 52.9 | 50.0 | 36.0 | |
| Perennials | <i>Phalaris arundinacea</i> | PHAR | 60.0 | 36.4 | 66.7 | 2.6 | | 8.0 | 1.1 | |
| | <i>Tamarix ramosissima + parviflora</i> | TARA | 33.3 | 72.7 | | | | | | |
| | <i>Tamarix</i> seedlings | TARAS | 60.0 | 27.3 | | | | | | |
| Hydrophytes | <i>Lythrum salicaria</i> | LYSA | 66.7 | 45.5 | | | | | | |
| Ruderal | <i>Ambrosia artemisiifolia</i> | AMAR | | | | 2.6 | 11.8 | 25.0 | 4.0 | 6.5 |
| Annuals | <i>Tribulis terrestris</i> | TRTE | 6.7 | 45.5 | | 15.8 | | | | 1.1 |
| (# of transects) | | n= | 15 | 11 | 3 | 38 | 17 | 4 | 25 | 93 |

Reach abbreviations: Weiser Reach (WR), Brownlee Reservoir - Headwater (BH), - Powder River Arm (BP), - Main (BM), Oxbow Reservoir - Main (OM), Hells Canyon Reservoir - Oxbow Bypass (OB), Hells Canyon Reservoir - Main (HM), and Snake River (SN).

Table 4.3. Average % cover of noxious or invasive plant species, per occupied quadrat per reach (the number of quadrats where the species was present is presented in parentheses).

| Vegetation Group | Species Scientific Name | Species Abbrev. | Weiser | Brownlee Reservoir | | | Lower Reservoir Reaches | | | Snake River |
|------------------------|---|-----------------|-----------|--------------------|-----------|-----------|-------------------------|----------|-----------|-------------|
| | | | (WR) | (BH) | (BP) | (BM) | (OM) | (OB) | (HM) | (SN) |
| Upland | <i>Agropyron repens</i> | AGRE | | | 10.5 (2) | | | | | |
| Annuals and Perennials | <i>Cardaria draba</i> | CADR | | | 18.3 (3) | 16.0 (3) | | | | |
| | <i>Cirsium arvense</i> | CIAR | 16.3 (19) | 5.0 (2) | 6.0 (3) | | | | | |
| | <i>Convolvulus arvensis</i> | COAR | 21.7 (14) | 4.8 (4) | | 20.3 (25) | 8.8 (4) | | 29.5 (4) | 4.1 (21) |
| | <i>Cynoglossum officinale</i> | CYOF | | | | 19.0 (4) | 7.3 (3) | | | 7.0 (1) |
| | <i>Euphorbia esula</i> | EUES | 7.0 (5) | | | | | | | |
| | <i>Hypericum perforatum</i> | HYPE | | | | | 7.0 (3) | | 5.0 (2) | 9.6 (73) |
| | <i>Linaria genistifolia</i> | LIGE | | | | 7.5 (4) | | | | |
| | <i>Onopordum acanthium</i> | ONAC | | 14.0 (1) | | 8.0 (6) | | | 7.0 (1) | 9.9 (8) |
| | <i>Taeniatherum caput-medusae</i> | TACA | 1.0 (1) | | 34.0 (2) | 17.5 (35) | 34.0 (23) | 3.0 (3) | 28.0 (8) | 5.0 (2) |
| Facultative | <i>Conium maculatum</i> | COMA | 5.9 (9) | | | | 63.5 (4) | | 14.0 (1) | 11.0 (4) |
| Riparian | <i>Lepidium latifolium</i> | LELA | 38.9 (33) | 33.1 (19) | | 23.0 (19) | 9.1 (19) | 7.0 (4) | 8.9 (8) | |
| Perennials | <i>Elaeagnus angustifolia</i> | ELAN | 55.6 (7) | 27.0 (1) | | 86.5 (1) | 22.7 (3) | | | |
| Obligate | <i>Cyperus esculentus</i> | CYES | 6.6 (13) | 9.4 (24) | | 7.5 (2) | | | | |
| Riparian | <i>Amorpha fruticosa</i> | AMFR | 20.4 (7) | 41.5 (13) | | 39.3 (27) | 38.2 (18) | 22.7 (3) | 44.4 (18) | |
| Perennials | <i>Phalaris arundinacea</i> | PHAR | 27.5 (25) | 9.5 (8) | 25.0 (11) | 27.0 (2) | | | 32.3 (4) | 14.0 (1) |
| | <i>Tamarix ramosissima + parviflora</i> | TARA | 31.5 (11) | 23.2 (43) | | | | | | |
| | <i>Tamarix</i> seedlings | TARA5 | 1.3 (24) | 1.3 (6) | | | | | | |
| Hydrophytes | <i>Lythrum salicaria</i> | LYSA | 5.0 (27) | 8.3 (12) | | | | | | |
| Ruderal | <i>Ambrosia artemisiifolia</i> | AMAR | | | | 7.0 (1) | 8.5 (2) | 7.0 (1) | 20.5 (2) | 3.5 (17) |
| Annuals | <i>Tribulis terrestris</i> | TRTE | 7.0 (1) | 6.1 (35) | | 3.0 (17) | | | | 3.0 (1) |

Reach abbreviations: Weiser Reach (WR), Brownlee Reservoir - Headwater (BH), - Powder River Arm (BP), - Main (BM), Oxbow Reservoir - Main (OM), Hells Canyon Reservoir - Oxbow Bypass (OB), Hells Canyon Reservoir - Main (HM), and Snake River (SN).

Table 4.4. Predicted differences across the proposed IPC Scenario versus the ROR scenario relative to noxious and invasive plant species that occur along the reservoir and river reaches.

| Vegetation Group | Species Scientific Name | Species Abbrev. | Common Name | Predicted difference with IPC vs. ROR scenario |
|------------------------|---|-----------------|-------------------------|--|
| Upland | <i>Agropyron repens</i> | AGRE | quackgrass | = |
| Annuals and Perennials | <i>Cardaria draba</i> | CADR | white-top / hoary cress | _ 1 |
| | <i>Cirsium arvense</i> | CIAR | Canada thistle | = |
| | <i>Convolvulus arvensis</i> | COAR | field morning-glory | = |
| | <i>Cynoglossum officinale</i> | CYOF | houndstongue | = |
| | <i>Euphorbia esula</i> | EUES | leafy spurge | _ 1 |
| | <i>Hypericum perforatum</i> | HYPE | common St. Johns Wort | = |
| | <i>Linaria genistifolia</i> | LIGE | dalmation toadflax | = |
| | <i>Onopordum acanthium</i> | ONAC | Scotch thistle | = |
| | <i>Taeniatherum caput-medusae</i> | TACA | medusahead wildrye | = |
| Facultative | <i>Conium maculatum</i> | COMA | poison hemlock | = |
| Riparian | <i>Lepidium latifolium</i> | LELA | perennial pepperweed | = |
| Perennials | <i>Elaeagnus angustifolia</i> | ELAN | Russian-olive | - / = |
| Obligate | <i>Cyperus esculentus</i> | CYES | yellow nut sedge | = |
| Riparian | <i>Amorpha fruticosa</i> | AMFR | false indigo | = |
| Perennials | <i>Phalaris arundinacea</i> | PHAR | reed canarygrass | = |
| | <i>Tamarix ramosissima + parviflora</i> | TARA | salt cedar complex | _ 1 |
| Hydrophytes | <i>Lythrum salicaria</i> | LYSA | purple loosestrife | ? |
| Ruderal | <i>Ambrosia artemisiifolia</i> | AMAR | common ragweed | = |
| Annuals | <i>Tribulis terrestris</i> | TRTE | puncture vine | + |

¹ Draw-down of Brownlee Reservoir would impede downstream dispersal.

Figure 4.1. Longitudinal occurrence of noxious and invasive plant species (abbreviations are listed in Tables 4.1, 4.2, and 4.3) along each reach in the IPC study corridor (Weiser = WR, Brownlee Reservoir - Headwater = BH, - Main = BM, - Powder Arm = BP, Oxbow Reservoir - Main = OM, Hells Canyon Reservoir - Oxbow Bypass = OB, Hells Canyon - Main = HM, and Snake River = SN).

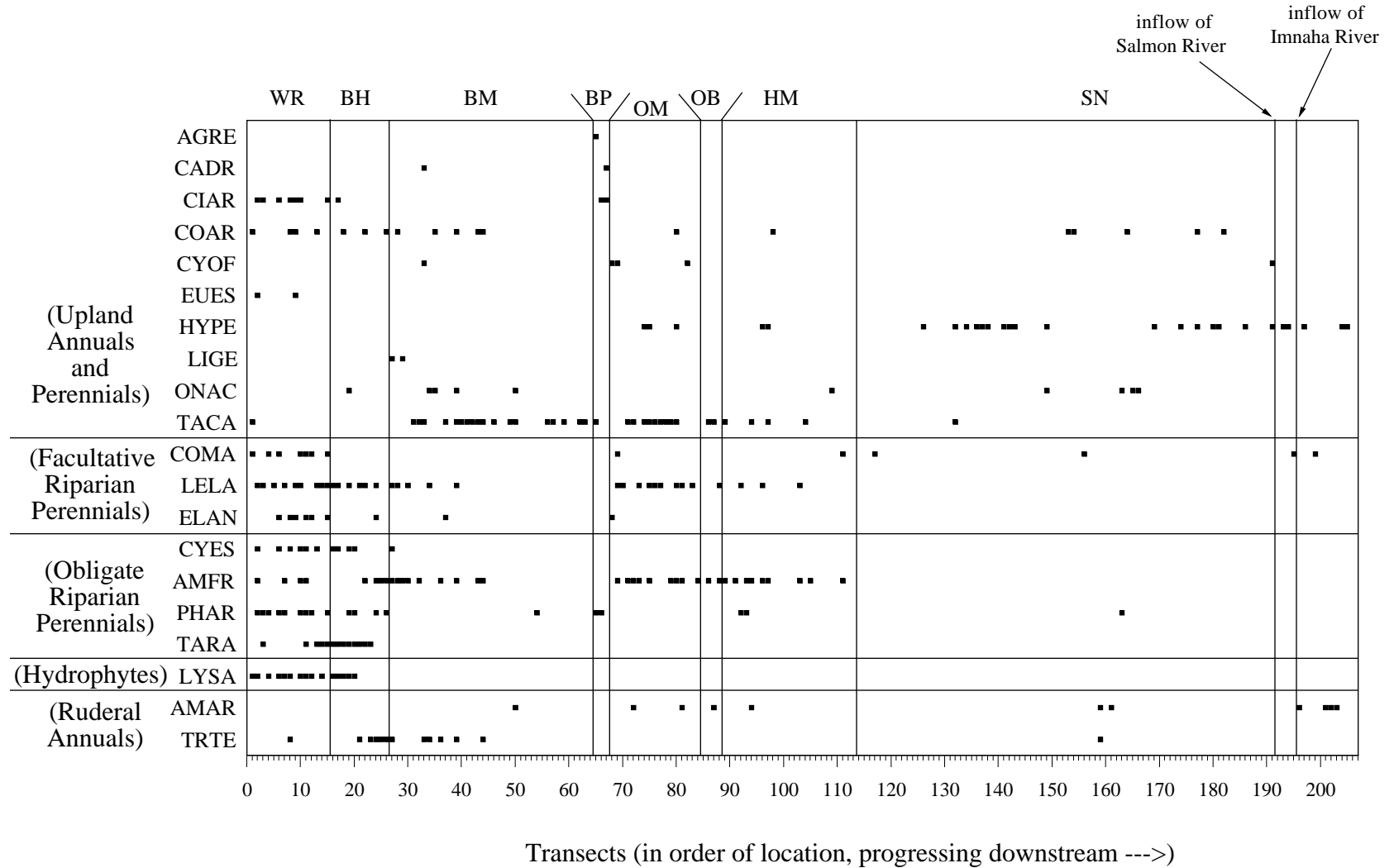


Figure 4.2. Proportions of all quadrats sampled along each reach at each elevation, that are occupied by upland noxious species (*Agropyron repens*, *Cardaria draba*, *Cirsium arvense*, *Convolvulus arvensis*, *Cynoglossum officinale*, *Euphorbia esula*, *Hypericum perforatum*, *Linaria genistifolia*, *Onopordum acanthium*, and *Taeniatherum caput-medusae*).

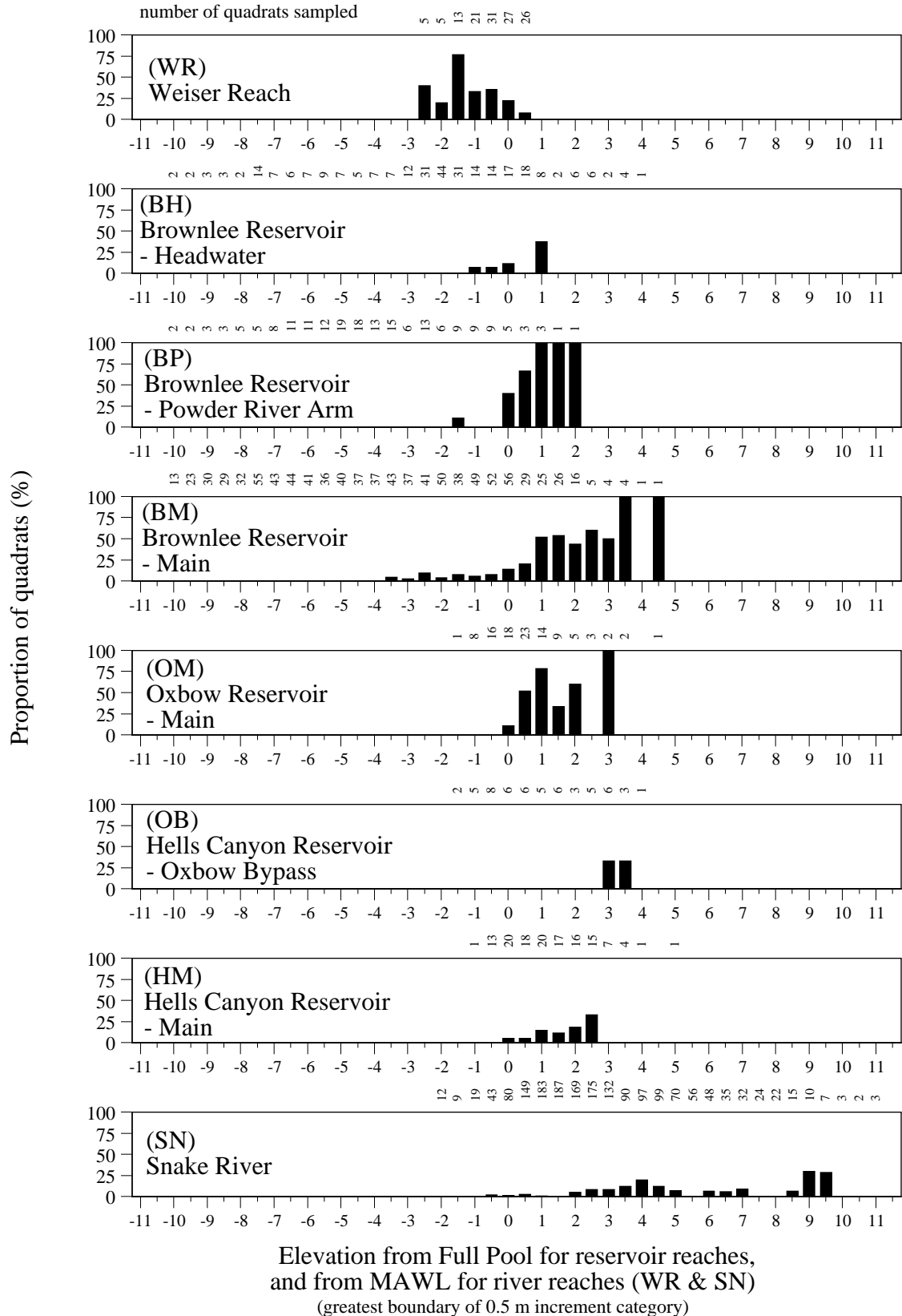


Figure 4.3. Proportions of all quadrats sampled along each reach at each elevation, that are occupied by the facultative riparian perennial, noxious or invasive species, *Conium maculatum* (COMA, poison hemlock), *Lepidium latifolium* (LELA, perennial pepperweed), or *Elaeagnus angustifolia* (ELAN, Russian olive).

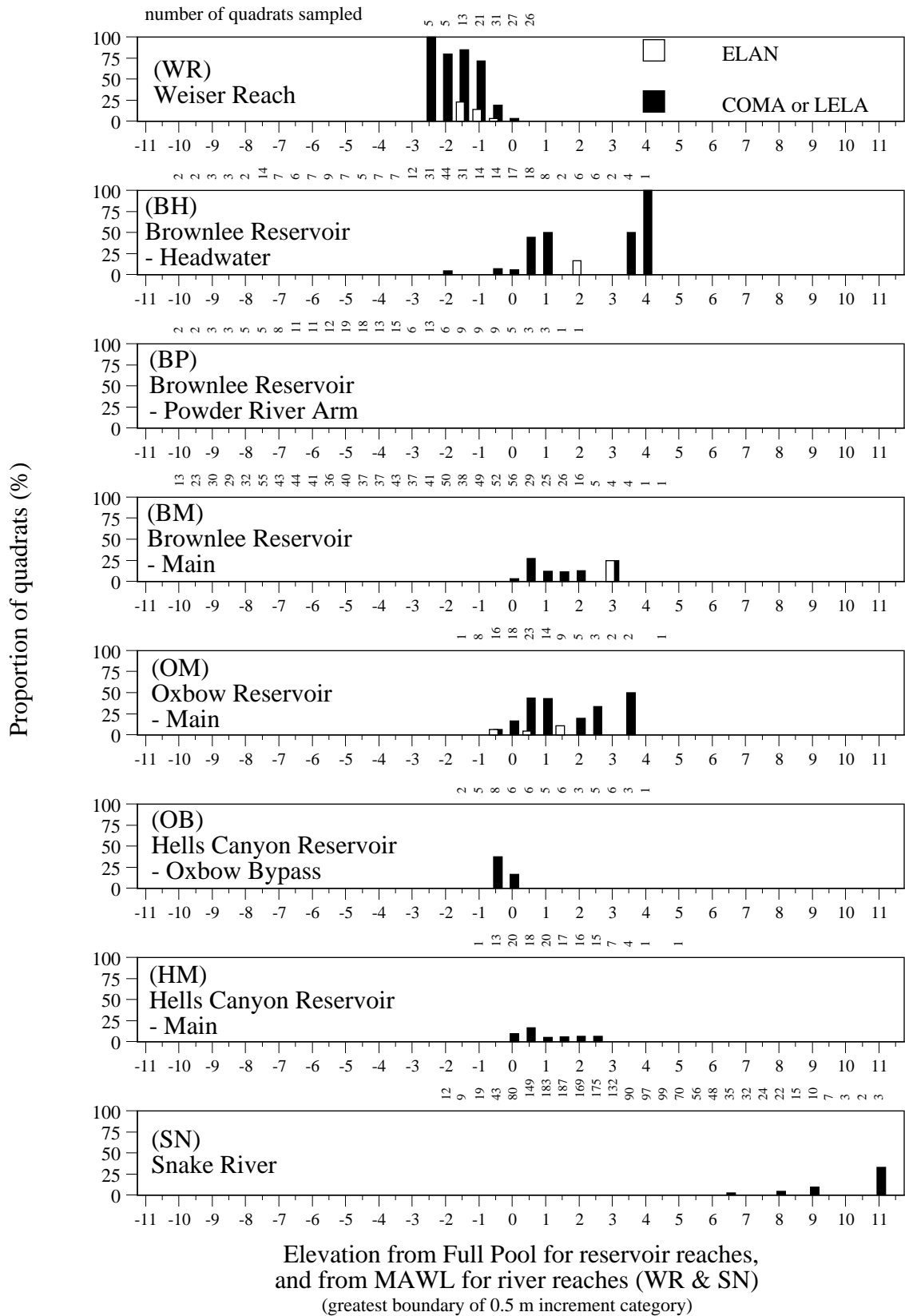


Figure 4.4. Proportions of all quadrats sampled along each reach at each elevation, that are occupied by the invasive tree, *Amorpha fruticosa* (AMFR, false indigo).

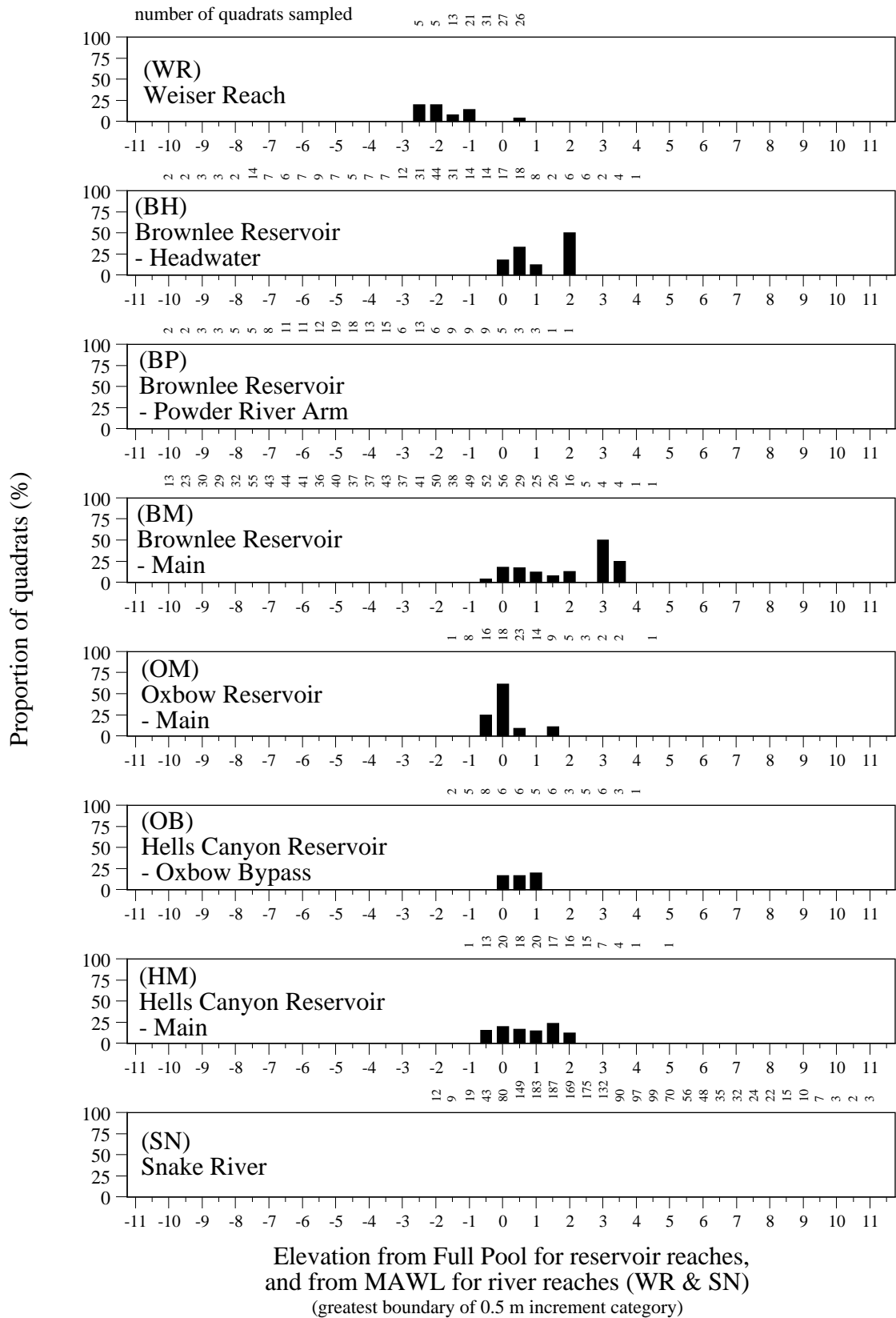


Figure 4.5. Proportions of all quadrats sampled along each reach at each elevation, that are occupied by the native perennial grass, *Phalaris arundinacea* (PHAR, reed canary grass).

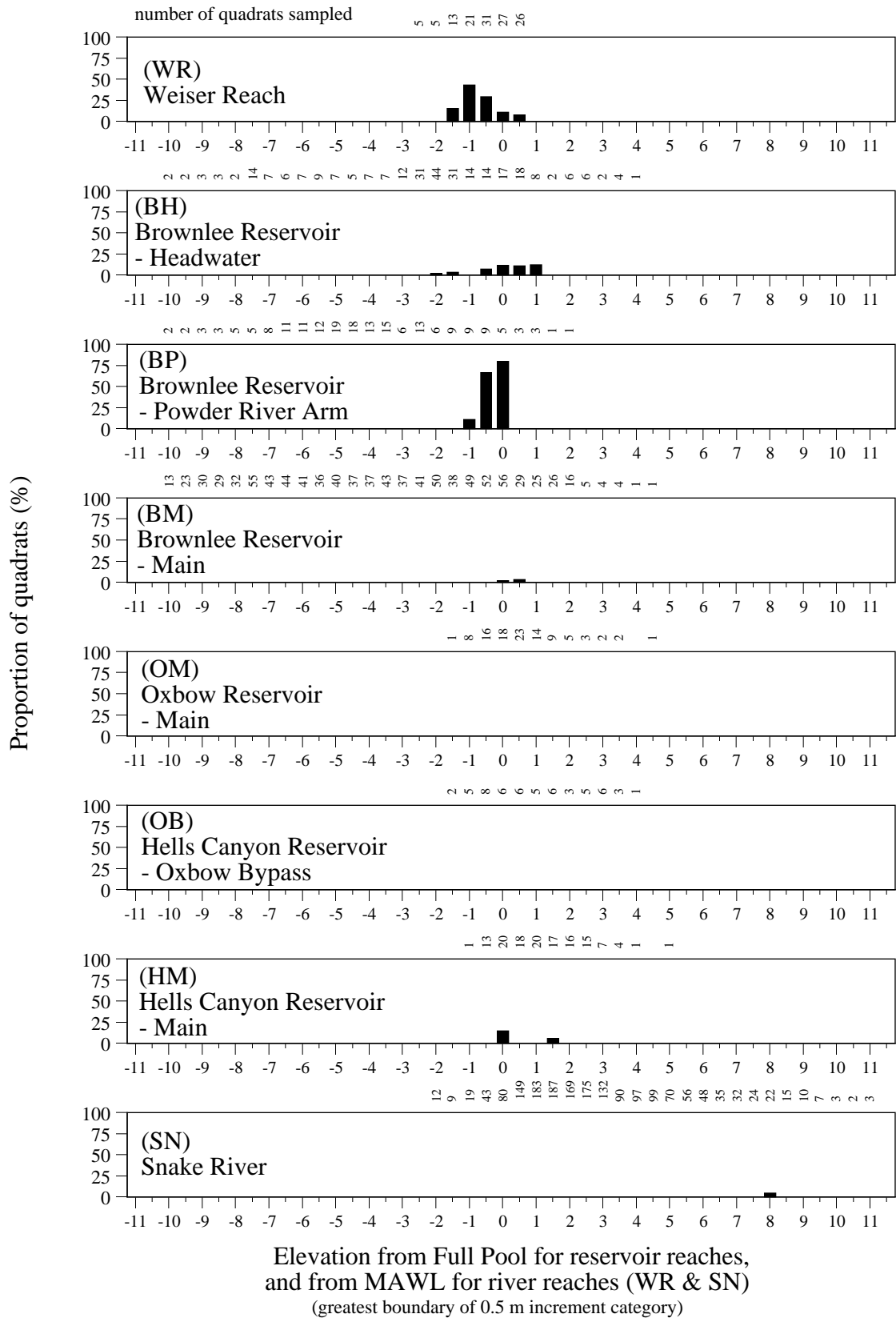


Figure 4.6. Proportions of all quadrats sampled along each reach at each elevation, that are occupied by the invasive, obligate riparian, woody tree / shrub, *Tamarix ramosissima* (TARA, tamarisk or salt cedar).

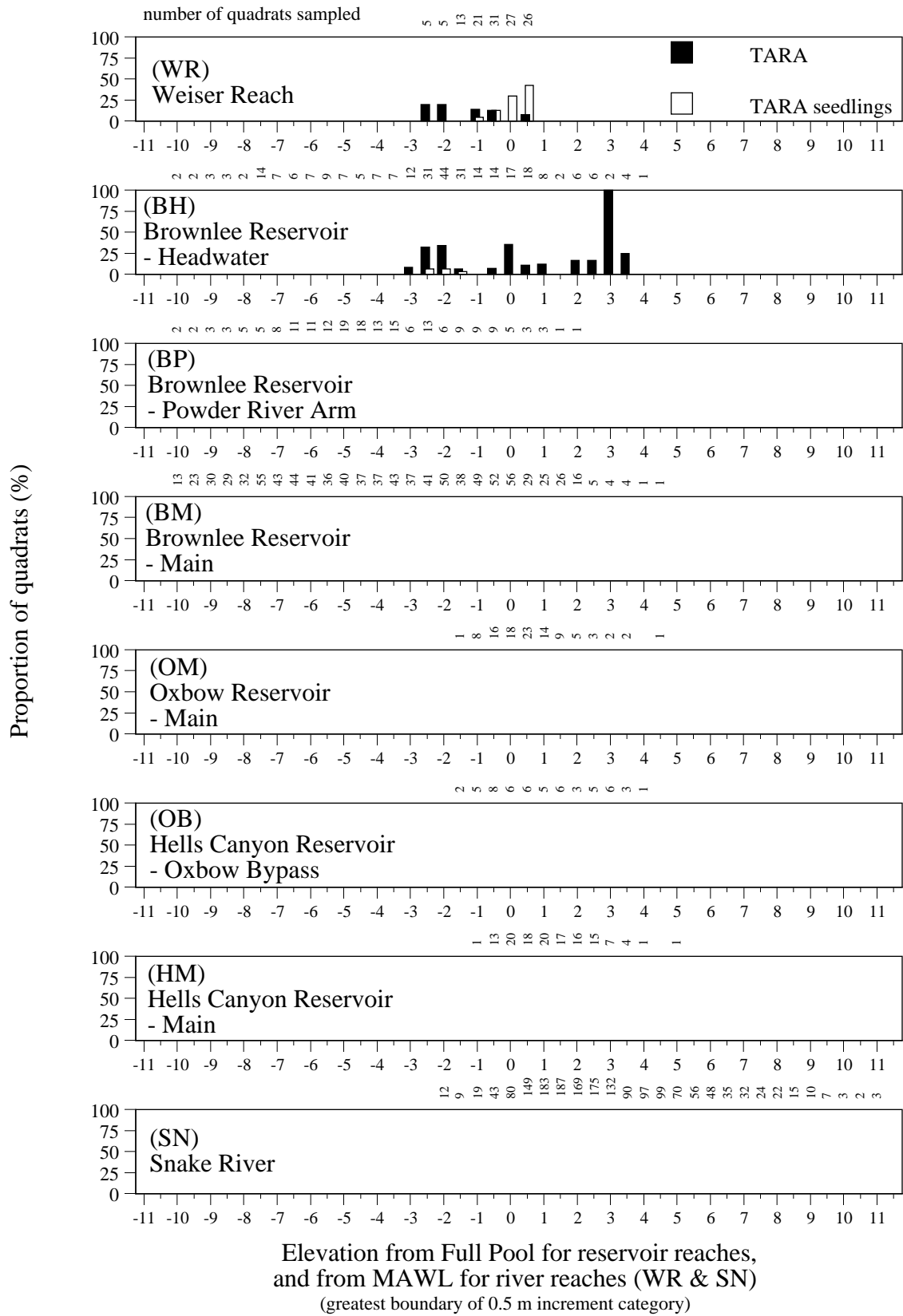


Figure 4.7. Proportions of all quadrats sampled along each reach at each elevation, that are occupied by the noxious hydrophyte, *Lythrum salicaria* (LYSA, purple loosestrife).

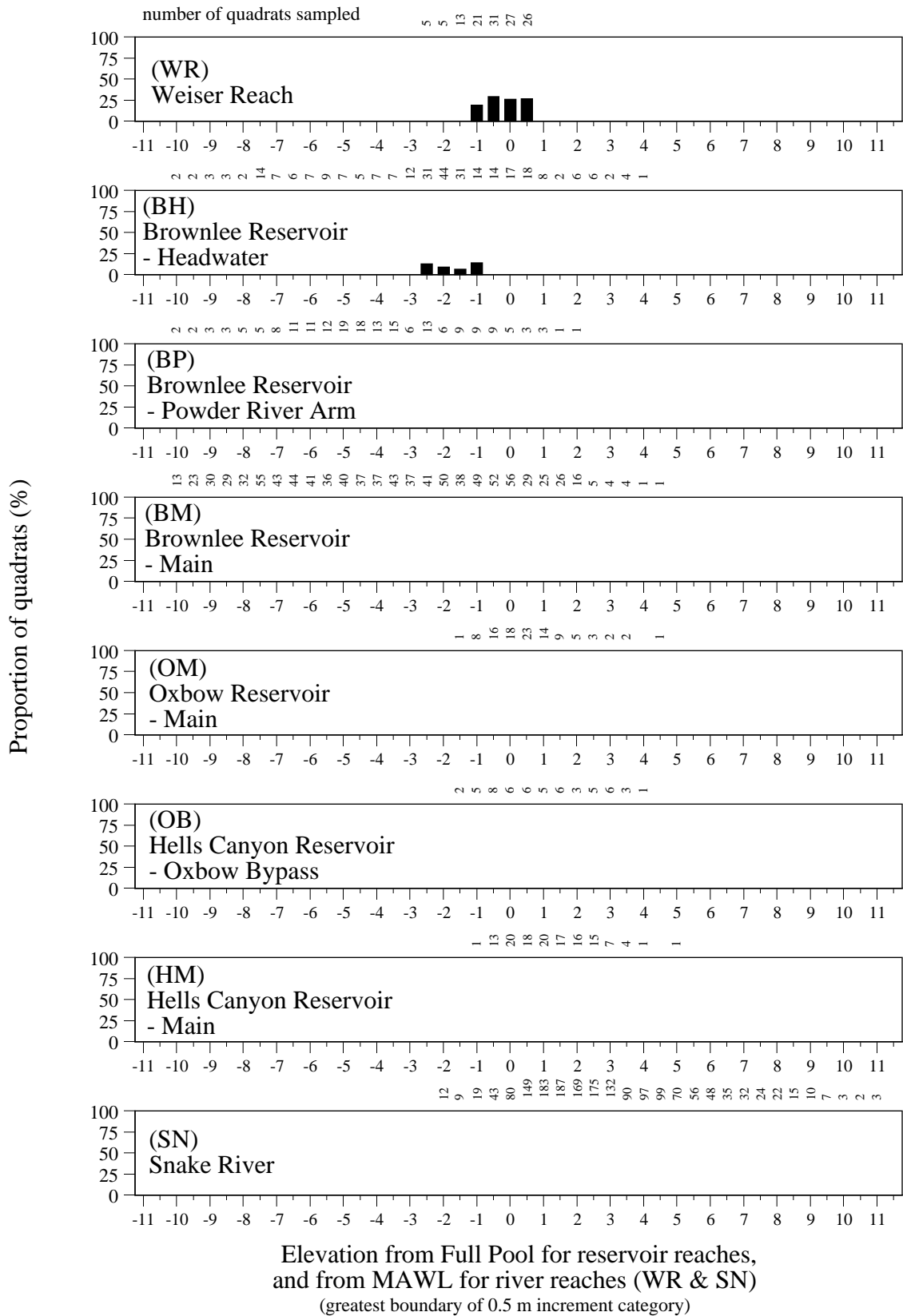


Figure 4.8. Proportions of all quadrats sampled along each reach at each elevation, that are occupied by the noxious ruderal annuals, *Ambrosia artemisiifolia* (AMAR, common ragweed) and *Tribulus terrestris* (TRTE, puncture vine).



CHAPTER 5: PROBABLE IMPACTS OF WATER MANAGEMENT SCENARIOS ON THE DISTRIBUTION OF RARE PLANTS ALONG RIPARIAN ZONES OF THE HELLS CANYON CORRIDOR

5.1. Introduction

In her seminal papers on the “Seven Forms of Rarity”, Deborah Rabinowitz (1981, 1986), reminds us that a central concern of conservation biology is the protection of rare species. Where the notion of “rarity” brings to mind organisms that are uncommon or unusual, and these rare species sometimes take on the added connotations of being fragile or valuable. Many biologists contend that rare species are more susceptible to extinction than common ones for a variety of reasons. Yet, as plant ecologists we often lack clear documentation of the geographic distribution and ecological properties of rare plants. This often leads to the lumping together of many different kinds of plants under the term “rare.” Unfortunately, this lack of precision not only obscures the biology of a very heterogeneous group of organisms, but also complicates the formulation of management strategies by various resource agencies (Rabinowitz et al. 1986).

To effectively manage rare plants, we need to understand what kinds of rarity exist, and in what ways rare plants differ from other plant species. Plants may be rare in several ways. They may occur only in a few scattered, isolated habitats or they may have a more widespread distribution in which each population consists of only a few individuals. Rarity is also temporally dynamic and may thus periodically arise from the inability of some species to morphological and physiologically adapt to changing environmental conditions. As noted by Rabinowitz (1981), all plant species possess three basic population traits:

1. **Geographic range**—A species can occur over a broad range or is endemic to a small, localized area.
2. **Habitat specificity**—A species can occur in a variety of distinct habitats or is restricted to only one or a few specialized habitats.
3. **Local population size**—A species may be found in either large or small populations within its range of distribution.

These three traits are continuous variables, but can be readily dissected into seven kinds of rarity (Table 5.1.).

Consistent with these implications of rarity, only a limited number of rare plant species were observed in the riparian zones along the Hells Canyon corridor. Only six vascular plant species identified during field sampling efforts by Holmstead (2001) and Krichbaum (2000) were classified as “rare plants” by state and federal agencies in Idaho and Oregon. These species included: Hazel’s prickly phlox (*Leptodactylon pungens* ssp. *hazeliae*), stalk-leaved monkey-flower (*Mimulus patulus*), Oregon bolandra (*Bolandra oregana*), porcupine sedge (*Carex*

hystricina), Schweinitz flatsedge (*Cyperus schweinitzii*), and American wood sage (*Teucrium canadense* var. *occidentale*). During the course of our field sampling efforts from 1998 to 2000, we did not observe rare plants along reservoir shorelines, but did encounter several populations of Schweinitz flatsedge (*Cyperus schweinitzii*), a relatively “rare” species within the riparian zone of the Hells Canyon Reach of the Snake River.

5.2. Rare Plants of the Hells Canyon Study Corridor

5.2.1. Threatened and Endangered Plant Species along Reservoir Reaches

In studies of populations along reservoir reaches by Krichbaum (2000), four species of special status plants were found to be potentially impacted by ongoing operations in the reservoir reaches. These included a) Hazel’s prickly phlox (*Leptodactylon pungens* ssp. *hazeliae*), b) stalk-leaved monkey-flower (*Mimulus patulus*), Oregon bolandra (*Bolandra oregana*), and porcupine sedge (*Carex hystricina*). However, no federally listed endangered or threatened species are known to occur along these reservoir reaches.

Leptodactylon pungens* ssp. *hazeliae—(Hazel’s prickly phlox)

Six populations of Hazel’s prickly phlox were found; one located below Hells Canyon Dam, and five along Hells Canyon Reservoir (Krichbaum 2000). There were seven previously known populations in the vicinity of the project. All of the newly located populations were found on dry, steep to vertical cliffs well above the mean high water mark (MHW). Plants in these locations would not be affected by patterns of reservoir management proposed by the two flow scenarios.

Conclusion: no difference across scenarios.

Mimulus patulus—(Stalk-leaved monkey-flower)

One population of stalk-leaved monkey-flower was found along Oxbow Reservoir (Krichbaum 2000). This population was found growing on gently sloping, damp, rocky ground in a road cut located well above the MHW at a lateral distance of approximately 20 m from the MHW of Oxbow Reservoir. Plants in this location would not be affected by the proposed pattern of dam operations.

Conclusion: no difference across scenarios.

Bolandra oregana—(Oregon bolandra)

Eight populations of Oregon bolandra were found; four in the reach below Hells Canyon Dam, one along Hells Canyon Reservoir, and three along Oxbow Reservoir (Krichbaum 2000). There were four previously known population of this species in the vicinity of the project, all on the Oregon side of the Snake River; two just north of Brownlee Dam, one below Hells Canyon Dam, and one near the confluence of Cow Creek and the Imnaha River. All were found growing near seeps or streams in cliffs, surrounded mostly by bare rock. Water status at these locations would not be affected by proposed dam operations.

Conclusion: no difference across scenarios.

Carex hystricina—(Porcupine sedge)

Ten populations of porcupine sedge were found; three below Hells Canyon Dam, and seven along Oxbow Reservoir (Krichbaum 2000). There were two previously known occurrences of this species in the vicinity of the project; one along Hells Canyon Reservoir, and one along Oxbow Reservoir. These populations were found growing in either relatively barren flow zones, or relatively lush riparian communities. These species were not observed in any of our reservoir or riverine transects (≥ 200 transects), yet, this species could potentially be affected by regulated flow regimes.

Conclusion: probably only minimal differences across scenarios. However, additional studies with specific life history modeling may be necessary to clarify the potential vulnerability of this species to different flow scenarios.

5.2.2. Threatened and Endangered Plant Species along the Hells Canyon Reach of the Snake River

In studies of plant populations along the Hells Canyon Reach of the Snake River (Krichbaum 2000), four species of special status plants were found to be potentially impacted by ongoing project operations below the dam; American wood sage (*Teucrium canadense* var. *occidentale*), Schweinitz flatsedge (*Cyperus schweinitzii*), Oregon bolandra, and porcupine sedge (Krichbaum 2000). No federally listed threatened or endangered species were found, although two populations of one federally threatened species, *Mirabilis macfarlanei*, are known to occur in the project vicinity, upslope of the river corridor below Hells Canyon Dam. Thus, no known federally listed endangered or threatened species would be impacted by operational patterns downstream of Hells Canyon Dam.

Teucrium canadense* var. *occidentale—(American wood sage)

One population of American wood sage was found in the reach below Hells Canyon Dam (Krichbaum 2000). There were three previously known occurrences of this species in the project vicinity; two in the reach below the dam and one near the mouth of the Weiser River in Idaho. The population found during this survey was growing on gently sloping, moist, rocky ground along the riverbank of the Snake River. Plants spanned the MHW, from about 15 cm above, to 75 cm below. Horizontal distance from the MHW ranged from one decimeter above, to two meters below. This species was not observed during our sampling of this reach, but nonetheless could be impacted by either current or proposed flow scenarios.

Conclusion: minimal difference across scenarios, but may require additional study.

Bolandra oregana—(Oregon bolandra)

Four populations of Oregon bolandra were found along the Snake River reach below Hells Canyon Dam (Krichbaum 2000). There was one previously known population of this species along the Hells Canyon reach of the Snake River and one near the confluence of Cow Creek and

the Imnaha River. All populations were found growing near seeps or streams in cliffs, surrounded mostly by bare rock. Since the observed populations were associated with water sources other than the Snake River, these locations would not be affected by different operational scenarios.

Conclusion: no difference across scenarios.

Carex hystericina—(Porcupine sedge)

Three populations of porcupine sedge were found along the Hells Canyon reach of the Snake River (Krichbaum 2000). There were two previously known occurrences of this species in the vicinity of the project; one on Hells Canyon Reservoir, and one on Oxbow Reservoir. These populations were found growing in either relatively barren flow zones, or relatively lush riparian communities. Flow zone disturbance was heavy at one site, and extreme at the other sites. This species was not observed during our sampling efforts (≥ 200 transects), but may be affected by current or proposed flow scenarios.

Conclusion: probably only minimal differences across scenarios. However, additional studies with specific life history modeling may be necessary to clarify the potential vulnerability of this species to different flow scenarios.

Cyperus schweinitzii—(Schweinitz flatsedge)

Twenty-one populations of Schweinitz flatsedge were found in the study area, all located in the reach below Hells Canyon Dam (Krichbaum 2000). All of these populations were situated near the river on dry, coarse, sandy loam soils of gentle to moderate slope. The majority of the sites (17 out of 21, or 81%) did not extend below the mean high water mark (MHW) into the river's flow zone. As current and proposed operations of HCC could potentially affect populations growing near the MHW, six populations of Schweinitz flatsedge were randomly selected to analyze their distribution patterns relative to seasonal flow regimes along the Hells Canyon Reach of the Snake River.

5.3. Sampling of Schweinitz Flatsedge Populations along the Hells Canyon Reach of the Snake River

Populations of Schweinitz flatsedge were only rarely encountered during the course of our sampling of the Hells Canyon Study Corridor (Figure 5.1.). However, on the basis of their relative distribution and abundance below Hells Canyon Dam, six populations of Schweinitz flatsedge were randomly selected out of the 21 populations recorded by Krichbaum (2000) for more intensive study in the Hells Canyon Reach of the Snake River. Belt-transect vegetation sampling protocols followed the sampling methods described in Chapter 2.

Among the six populations sampled, the elevational distribution of Schweinitz flatsedge ranged from 2.57 m to 6.6 m above the mean annual water level ($n = 24$, mean = 4.43 m above MAWL, Table 5.2., Figure 5.2.). These populations also occur well above mean annual peak flows (mean = 2.10 m above AVEMAX, Table 5.2.), yet are subject to inundation during relatively infrequent

historic peakflow events. (mean = -1.05 m below MAX, Table 5.1.). Their relative abundance was low to moderate, ranging from 1 to 27% cover per sample plot (mean = 9.8% cover, Table 5.2.). This pattern of distribution indicates that populations of Schweinitz flatsedge were located toward the upper end of the facultative riparian zone; an area only rarely inundated by scouring peak flows. Situated at these high elevations, these plants would be minimally influenced by the differences in flow patterns across the two scenarios.

Conclusion: minimal difference across scenarios.

5.4. Conclusions Regarding Probable Impacts of Flow Scenarios on Rare Plants

On the basis of several investigations, it appears that potential impacts on rare plant populations will not differ significantly between the two flow scenarios. This conclusion is largely based on the combination of a) extensive field inventories of rare plant populations within the study corridor (Krichbaum 2000, Holmstead 2001), and b) more intensive sampling of Schweinitz sedge, a rare species along the Hells Canyon Reach of the Snake River. Only in some limited cases, would additional studies of the life history, ecology and distributional patterns of select species be warranted. Almost all of the rare plants observed in the study corridor were found in upland areas adjacent to riparian zones. Schweinitz sedge, porcupine sedge and wood sage were found in riparian zones where annual peak flows occasionally inundate isolated, local populations of these rare species. However, these populations are regularly exposed to such flow conditions. Further, annual and historic peak flows do not differ significantly between flow scenarios, thus we anticipate only minimal impacts, if any, upon local populations of rare plants within the study corridor. These conclusions are also largely consistent with the findings of Krichbaum (2000) and Holmstead (2001).

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Table 5.1. Seven forms of rarity, based on three population traits.

| Geographic distribution Habitat specificity | Wide | | Narrow | |
|--|-------|------------|--------|------------|
| | Broad | Restricted | Broad | Restricted |
| Populations large somewhere | 1 | 2 | 3 | 4 |
| Populations everywhere small | 5 | ** | 6 | 7 |

** Only combination of variables in which the occurrence of rare plants has not been documented (Modified from Rabinowitz 1981, 1986)

Table 5.2. Elevational distribution (m) and relative abundance (% cover) for randomly selected populations - Schweinitz flatsedge (*Cyperus schweinitzii*) along the Hells Canyon Reach of the Snake River.

| Quadrat # | River Mile | * | ** | *** | % Cover | % Cover |
|-----------|------------|---------|-----------|--------|---------|---------|
| | | EfrMAWL | EfrAVEMAX | EfrMAX | BARE | CYCS |
| 059B001 | 229.81 | 4.93 | 3.04 | 0.24 | 86.5 | 14 |
| 059B002 | 229.81 | 4.79 | 2.90 | 0.10 | 86.5 | 14 |
| 059B003 | 229.81 | 4.64 | 2.75 | -0.05 | 86.5 | 27 |
| 059B004 | 229.81 | 4.57 | 2.68 | -0.12 | 86.5 | 27 |
| 059B005 | 229.81 | 4.37 | 2.48 | -0.32 | 86.5 | 7 |
| 059B006 | 229.81 | 4.13 | 2.24 | -0.56 | 86.5 | 7 |
| 059B008 | 229.81 | 3.78 | 1.89 | -0.91 | 86.5 | 7 |
| 065001 | 218.45 | 3.11 | 1.14 | -1.56 | 86.5 | 3 |
| 065002 | 218.45 | 2.73 | 0.76 | -1.94 | 86.5 | 14 |
| 172003 | 217.38 | 4.04 | 1.93 | -1.10 | 86.5 | 3 |
| 181011 | 204.45 | 6.64 | 4.07 | 0.71 | 54 | 3 |
| 181012 | 204.45 | 6.64 | 4.07 | 0.71 | 54 | 14 |
| 181016 | 204.45 | 6.24 | 3.67 | 0.31 | 27 | 3 |
| 181017 | 204.45 | 5.89 | 3.32 | -0.04 | 27 | 14 |
| 181018 | 204.45 | 5.65 | 3.08 | -0.28 | 14 | 27 |
| 181019 | 204.45 | 5.43 | 2.86 | -0.50 | 7 | 7 |
| 210019 | 211.93 | 3.07 | -0.16 | -4.20 | 86.5 | 7 |
| 210028 | 211.93 | 4.37 | 1.14 | -2.90 | 54 | 3 |
| 210029 | 211.93 | 4.23 | 1.00 | -3.04 | 54 | 7 |
| 210030 | 211.93 | 4.50 | 1.27 | -2.77 | 54 | 7 |
| 211018 | 218.40 | 2.57 | 0.60 | -2.12 | 86.5 | 1 |
| 211019 | 218.40 | 2.74 | 0.77 | -1.95 | 54 | 7 |
| 211020 | 218.40 | 2.86 | 0.89 | -1.83 | 27 | 3 |

* EfrMAWL ~ Elevation (m) relative to mean annual water level (MAWL)

** EfrAVEMAX ~ Elevation (m) relative to mean annual peak flows (AVEMAX)

*** EfrMAX ~ Elevation (m) relative to maximum peak flows (MAX)

BARE = % Bareground/sample plot (octave coverage classes)

CYCS = % *Cyperus schweinitzii*/sample plot (octave coverage classes)

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Figure 5.1. Proportions of all quadrats sampled along each reach at each elevation, that are occupied by the threatened species, *Cyperus schweinitzii* (CYSC, Schweinitz flatsedge).

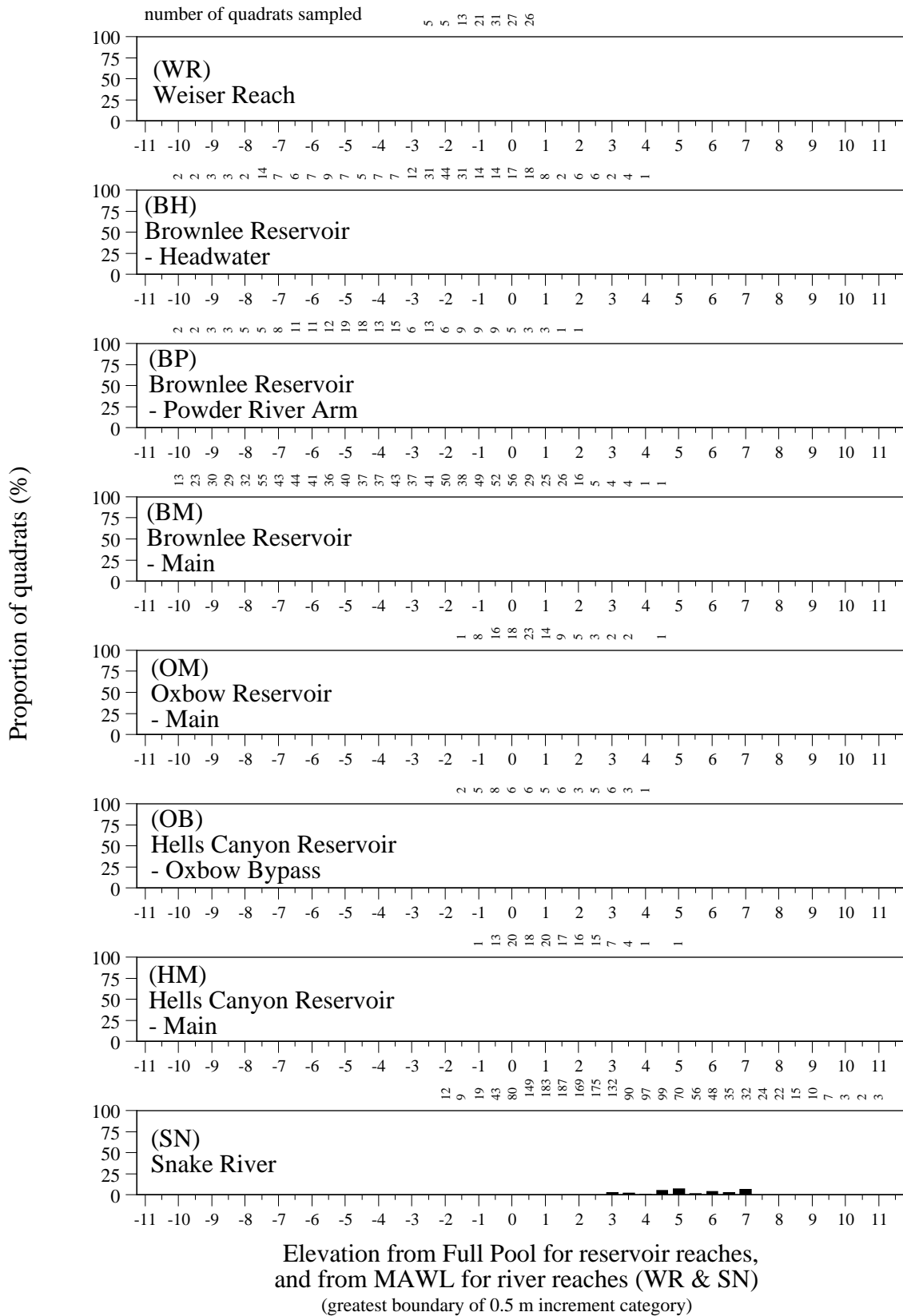
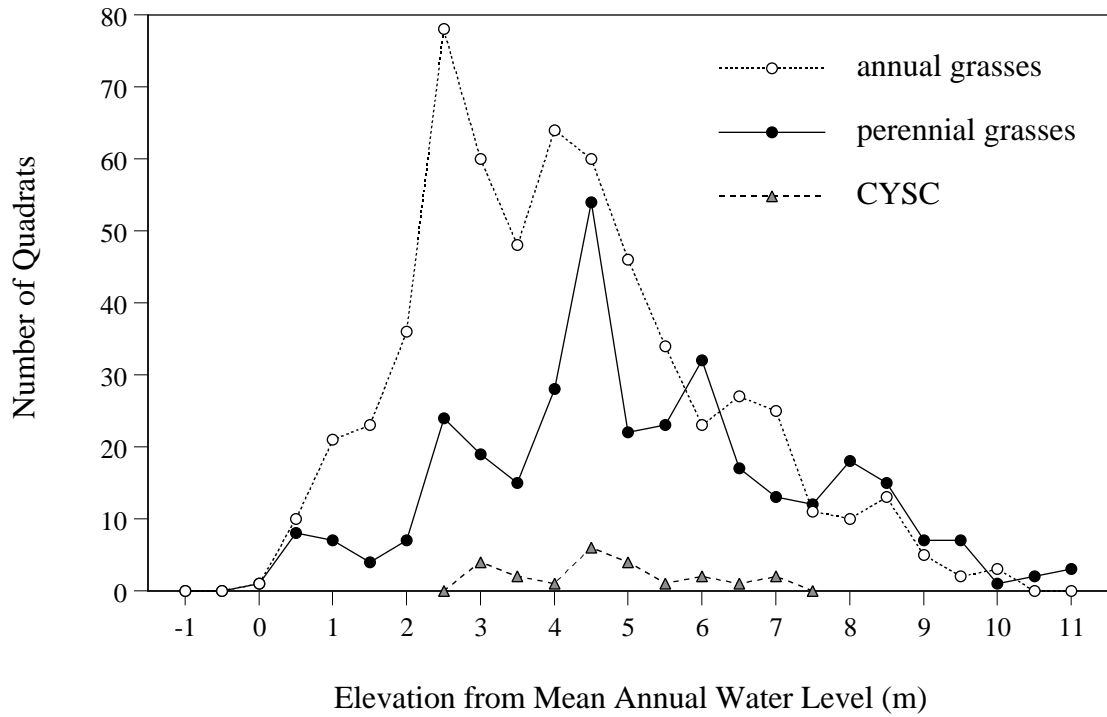


Figure 5.2. Elevational distribution of *Cyperus schweinitzii* (Schweinitz flatsedge) in relation to graminoid species surveyed along the shoreline of the Snake River Reach (SN) from 1998 to 2000 (species included in each category are listed in Appendix 2.1.).



CHAPTER 6: OVERVIEW OF MODELED RESPONSES OF RIPARIAN PLANTS TO PROPOSED AND RUN OF RIVER OPERATIONS OF THE HELLS CANYON PROJECT

6.1. Introduction

The present study investigated the hydroecology of riparian vegetation of the Hells Canyon Corridor of the Snake River. The study included field data collection at about 200 vegetation transects along the Snake River near Weiser, the three reservoirs of the Hells Canyon Complex (Brownlee, Oxbow and Hells Canyon reservoirs), and along the Snake River from Hells Canyon Dam to the confluence with the Salmon River. Statistical analyses were conducted investigating the relationships between vegetation distribution, substrates and water level patterns.

A computer model, the Hells Canyon_River Environment Model (HC_REM), was developed, calibrated, verified, and applied to predict the effects of inundation and regulated flows associated with two operational scenarios on plant distributions. The detailed results of these study components were presented and discussed in previous chapters of this report. The evaluation represents a three-level process as presented in Chapter 1 and executed in Chapters 2 through 5 where (1) qualitative and quantitative patterns are analyzed, (2) a computer modeling approach is undertaken with refinement and validation to produce confident results, and (3) these results are assessed relative to professional judgment to ensure that resultant patterns are consistent with the current understanding of hydrogeomorphic and ecophysiological requirements of riparian plants. Initial qualitative inputs arose from professional judgment and experience with riparian zones along numerous river and reservoir systems across western North America. Quantitative input came from examination of the field results and the statistical analyses that related vegetation responses to historical water surface elevation patterns. These provided the basis of the model application that predicted vegetation responses to water surface elevation patterns that differ somewhat across the two operational scenarios.

The purpose of these efforts was to provide information that will be useful in assessing the overall effects of future operation of the Hells Canyon Complex on riparian vegetation that provides various contributions to the riverine ecosystems, including the provision of terrestrial habitat for wildlife. The overall results are summarized and evaluated in this final chapter of the report.

6.2. Hydrology, Fluvial Geomorphology, Sediment Transport

Riverine ecosystems, including riparian vegetation are largely dependent upon physical processes of hydrology, fluvial geomorphology, and sediment transport. Flow in the Snake River basin follows a typical snowmelt hydrograph pattern as watershed run-off is contributed from melting snow in the upper portions of the basin. This generally produces higher flows in the

spring and declining flows in the summer and due to the semi-arid climate of Hells Canyon, local precipitation inputs provide reduced contributions to the overall hydrograph. However, the seasonal hydrograph pattern is punctuated by occasional significant rainfall events that occur unpredictably throughout the year (Simons et al. 2001).

Hydrology and Hydroecology

Vegetation along the river and reservoir reaches of the Snake River corridor is largely dependent upon moisture that originates from the adjacent river or reservoir. Within the semi-arid region, local precipitation along the river valley is insufficient to support extensive woodlands and thus trees and shrubs primarily occur along riparian zones that line the river and reservoir and also tributary drainages. Locally adapted plants are dependent upon the varying water levels that are associated with the seasonally variable upstream inflows that are modified by regulation through dam operations.

Typically, vegetation can expand in coverage as seeds and/or clonal propagules are dispersed and germinate or grow during the spring and summer. During this period flow and water levels generally peak and subsequently recede. These hydrograph patterns principally result from the snowmelt peak and flows fall to their lowest levels of the growing season through the dry period of summer. These low flows expose moist substrates that provide potential sites for plant colonization.

In order to survive over the long-term, successful vegetation must endure desiccation stress as the water level recedes and temperatures climb through the summer. Assuming that the vegetation remains viable through the summer, plants must then survive subsequent periods of inundation as well as hydraulic stresses associated with the higher flows associated with next season's snowmelt peak. The potential expansion of vegetation also requires that seeds fall on suitable substrate that consists of sufficient fine-sized particles; such as sand, silt, or clay often intermixed with the predominantly coarser substrates of Hells Canyon. With respect to overall hydrologic impacts, the Hells Canyon Complex (HCC) has limited effects on the hydrology of the Snake River downstream because the HCC storage capacity is only about 10% of the mean annual volume of the Snake River (Parkinson et al. 2002). Consequently, the HCC does not eliminate major flood flows as can occur along some other regulated streams with proportionally larger storage reservoirs.

Fluvial Geomorphology

The quality and quantity of substrates that are required for vegetation establishment and survival demand that aspects of fluvial geomorphology and sediment transport are incorporated into ecological models that predict vegetation patterns. At the upper end of the study reach near Weiser, the Snake River meanders through a relatively broad alluvial plain with dominant sediments consisting of sand and silt overlying gravel and cobble. However; once the river enters the confined reach of Hells Canyon the river valley is dominated by rock. The rock occurs as small fragments of steep talus slopes, boulder fields, and massive bedrock outcrops. Some finer materials are found in portions of the interstices between individual rock particles or in cracks in the rock as well as in occasional small to large sand bar deposits. Vegetation cannot become

established on solid rock or in boulder fields and thus occurs where sufficient quality and quantity of finer sized materials are present.

The extent of the various types of geomorphic features and substrates found along the river were documented in the geomorphic classification of the Snake River downstream of Hells Canyon Dam (Miller et al. 2002). This geomorphic classification revealed that the vast majority of the riverbanks consist of either bedrock or coarse colluvial material that is immobile under the normal range of flow conditions. Thus, the range of flows that are typically experienced from season to season, year to year, decade to decade, or even century to century, cannot significantly influence the fluvial geomorphology of much of Hells Canyon. While the Bonneville Flood influenced the fluvial geomorphology of Hells Canyon, this magnitude of flood is well beyond any that is considered in the normal hydrology of the Snake River. Thus, the basic structure and composition of the existing geomorphic features of the Snake River are expected to persist with little change for the future of the license term (barring some major catastrophic event such as an extreme earthquake). This assessment of the static nature of Hells Canyon is consistent with the analysis by Valier (1998) and by Parkinson et al. (2002):

“Because the basic form and character of the river were established under vastly higher flow conditions, the bed and bank materials provided extremely limited opportunity for river movement.”

This does not mean that absolutely no change occurs to the bed and banks of the Snake River through Hells Canyon, but rather that change is very limited in magnitude and extent. There are some areas of minor riverbank erosion and there is very gradual erosion of bedrock, but the duration for this process is vastly longer than the life cycles of the riparian plants. An exception to this static nature of the physical river valley through Hells Canyon relates to sand bars.

Sediment Transport

The present study did not analyze or model aspects related to sediment transport. Previous analyses by Grams and Schmidt (1991), Blair et al. (2001) and Miller et al. (2002) were used to consider the influences of sedimentation processes on riparian vegetation. There would be minimal changes in sediment transport across the two scenarios modeled and thus the conditions of this physical factor would be very similar with the proposed scenario and the ROR scenario.

Although not included in the HC_REM model, sediment transport can be very important relative to riparian vegetation. Large dams lead to sediment trapping as suspended particles settle out in the slow-moving reservoir waters (Williams and Wolman 1984). Consistent with this universal pattern, along the Snake River below Hells Canyon Dam, Grams and Schmidt (1991) demonstrated diminishment in sand bars, which were already relatively infrequent and isolated, after completion of the HCC. However, Grams and Schmidt (1991) did not evaluate aerial photographs prior to 1964 when Brownlee Dam was completed. Thus, a decline in sandbars prior to 1964 was not assessed by the authors. As discussed below, these reductions can be attributed to several different factors, including basin-wide sediment trapping upstream of the HCC, increased regulatory control over watershed disturbances reducing sediment supply, and additional incremental sediment trapping by HCC itself. The change in sediment status would

have negatively impacted riparian vegetation, to some degree, particularly of some plants such as the sandbar willow, *Salix exigua*, that occur along sandbar fringes (where coarser material is found, which provides some greater degree of stability than the ever-shifting and unstable sand surfaces that are generally incapable of supporting significant perennial vegetation), and also more broadly in positions where sand settles into pockets between colluvial boulders and bedrock.

In addition to considering the local-scale, post-Hells Canyon Dam patterns of sandbars, it is also appropriate to consider longer-term and broader spatial-scale aspects of sediment input and transport (Blair et al. 2001). With respect to natural dynamics, the slope of the Snake River in the Hells Canyon reach is about four times steeper than the river reach through the Weiser. Subsequently, velocities are swifter through the Hells Canyon reach and the higher velocities have higher competencies; the capacity to mobilize and transport sediments. Consequently, in an unaltered, free-flowing condition the Hells Canyon reach would generally be sediment-deficit with respect to the upstream supply of sediment versus the capacity to transport sediments through the canyon. Based on a ratio of slopes and sediment transport capacities, this deficit would be a factor of 8 to 16 (Blair et al. 2001).

Due to the relative deficiency of sediment supply relative to the sediment transport capacity, finer sediments are readily transported through Hells Canyon. Thus little deposition of fine sediments occurs in Hells Canyon and prior to flow regulation, the river valley was dominated by bedrock rather than alluvium. Alluvial deposits would occur sporadically in the form of sand and gravel bars along channel margins, typically in eddy and backwater areas where hydraulic conditions permit sediment deposition. These patterns are consistent with historic photographs (Blair et al. 2001).

With respect to sediment patterns over recent decades, consideration should be made to land use impacts in the watershed. As the watershed was developed in the late 1800s and early 1900s, land-use activities such as agriculture, grazing, mining, and timber harvesting, disturbed the land and released far more fine sediments than would have occurred under natural conditions. As land use practices have been altered to reduce land erosion, there has probably been a substantial reduction in sediment release (Blair et al. 2001). Thus, there would probably have been reduced sediment inputs into the Snake River over the past few decades. Therefore, Parkinson et al. (2002) concluded that

“Human activities in and above the Hells Canyon area, such as mining and grazing, modified hill slope processes from the mid-1800s to the mid-1900s. These activities probably introduced an unusually large sediment supply to the river that decreased as the activities that introduced them also decreased. This “slug” of sediment may be working its way out of the Hells Canyon system.”

Additionally, upstream water resource developments in the form of large dams on the Snake River and its tributaries would significantly reduce the drainage area that contributes sediment to the Weiser Reach at the upstream end of the study area. In assessing watershed maps Miller et al. (2002) concluded that less than eight percent of the overall sediment-contributing drainage area was cut off by the Hells Canyon Complex, while over 92 percent of the sediment-contributing

drainage area was cut off by other upstream water storage projects on the Snake River and its tributaries.

Thus, coincident with the installation of the Hells Canyon Complex, two additional major changes would have led to reductions of sediment inputs, (1) changing land use practices that diminished sediment release in the watershed and (2) extensive upstream damming. At the local scale, although diminished due to upstream damming and general increase in watershed sediment control, the Weiser reach of the Snake River upstream of the Hells Canyon Complex still contains substantial sand and other fine sediments since this reach is a flatter alluvial channel compared to the steeper, rock-dominated canyon farther downstream. Some of these finer sediments would continue to be mobilized with high flows in the Weiser Reach and the Hells Canyon Complex will continue to trap most of these sediments. However, Parkinson, et al. (2002) demonstrated that less than 4% of the sediment trapped in Brownlee Reservoir is larger than fine sand, suggesting that little of the sediment trapped in the HCC is likely to have contributed to the development of sandbars.

Substantial quantities of fine sediment still remain in the interstitial spaces between larger rocks and also underlying the coarser armor layers. These sediments are likely to remain in place over the period of the subsequent license due to armoring and the ‘hiding effect’ that shelters finer sediment deposits between and below large particles. The existing fine sediment provides some of the substrate that supports the current riparian vegetation and will be expected to continue to support vegetation in the future.

Thus, while substantial changes have occurred over the past century, observation and qualitative evaluation suggest that future trends would probably not have major effects on sediment and the vegetation it supports over the term of the next license and relative to the current comparison, sediment patterns would not differ substantially across the two operations scenarios. In either case, the diminished sediment inputs from the Weiser reach would largely settle out in Brownlee Reservoir. Very fine sediments would remain in suspension along the reservoirs and would largely pass through the Hells Canyon reach of the Snake River due to the increased gradient, velocity and turbulence. Clear water releases would continue downstream from Hells Canyon Dam but many of the readily mobile sediments have already been exported. Sediment supplies from tributaries downstream of the HCC continue to provide a wide range of particle sizes including fine material to the Snake River (Parkinson et al. 2002).

6.3. Modeled Responses of Riparian Plants to Hells Canyon Operations

As described in the prior sections, the current project involved a deterministic, hydrogeomorphic model that assessed probable vegetation impacts across different water management scenarios. With the verification process described in Chapter 3, we consider that this approach was appropriate for the Hells Canyon Corridor.

The success in the modeling effort partly relates to the unusual nature of the study reaches. Hells Canyon provides an exceptionally ‘hard’ landscape in which bedrock is a dominant feature in a deeply incised V-valley. This landscape contrasts to alluvial river reaches that are more common

across western North America. Along alluvial channels, the sediments are periodically mobilized during moderate to high flow events and consequently alluvial channels are naturally dynamic. This dynamic is critical to create nursery sites for pioneering riparian vegetation and consequently the dynamics of channel meandering and migration and of sediment transport demand consideration. In contrast, the deeply incised, bedrock-confined channel through Hells Canyon is virtually inert over the time frame associated with the life histories of the local riparian plants. This removes much of the fluvial geomorphic dynamic that would impose an additional level of complexity to any modeling approach. While we thus consider that Hells Canyon represents a simpler riparian system to model than many alluvial reaches, we also consider that the general modeling approach developed as HC_REM will also be broadly applicable.

As indicated in Chapter 3, the seven study reaches can be clustered in three groups with generally similar patterns of water stage change and correspondingly similar responses to the two different operations scenarios. Progressing downstream, the first group includes the three reaches along the Brownlee Reservoir. The second group, designated as the ‘lower reservoir reaches’, includes the shoreline reaches along Oxbow Reservoir, the transitional reach of the Oxbow Bypass, and the lower Hells Canyon Reservoir. The third study reach category consists of the reach of the Snake River between Hells Canyon Dam and the confluence with the Salmon River.

Brownlee Reservoir Reaches

Relatively similar differences across the two water management scenarios were predicted for the three Brownlee Reservoir Reaches (Table 6.1.). In each case, the greatest differences in riparian vegetation were predicted to be associated with the increased storage reservoir draw-down of the proposed scenario. This will expose barren areas that would be available for colonization by ruderal annuals (Table 6.1.). The model predicts 2- to 6-fold increases in this vegetation group with greater increases associated with the Brownlee Headwater and, especially, Powder River Arm reaches of the reservoir. With more gradually sloping delta zones along those transitional reaches, extensive areas would be available for colonization by the weedy ruderal annuals.

The model predicts that the draw-down associated with the proposed scenario would also slightly favor facultative riparian annuals with increases of 11, 11 and 21% for the three Brownlee Reservoir reaches (Table 6.1.). However, while the model predicts that this vegetation group would occupy a broader range of elevations with the proposed scenario, the model does not incorporate plant competition and consequently this prediction may be inflated. The other group of riparian annuals, the obligate riparian annuals is also predicted to slightly increase with the proposed scenario (Table 6.1.) but, again, competition should diminish the extent of this difference.

Relative to wildlife habitat, the riparian perennials are especially important and the model predicts contrasting differences relative to these vegetation groups (Table 6.1.). The reservoir draw-down associated with the proposed scenario would diminish water availability in the higher riparian zones and consequently the model predicts a decrease in the facultative riparian vegetation for the Brownlee Headwater and Brownlee Main reaches. A slight opposite pattern is

predicted for the Powder Arm since this vegetation group would be predicted to expand downward, compensating for the less favorable high elevations conditions.

In contrast to the patterns for the facultative riparian perennials, the model predicts more favorable conditions with the proposed scenario for obligate riparian perennials due to an elevational expansion of this vegetation group. In considering the changes in both the facultative and obligate riparian perennials, the model suggests that with the proposed scenario there would be little net change along the Brownlee Headwater reach as the increase in obligate riparian perennials would be similar in magnitude to the decrease in facultative riparian perennials. Along the main Brownlee Reservoir the model predicts a net reduction in riparian perennials due to the substantial reduction in the facultative riparian perennials. Conversely, the model predicts a net increase in riparian perennials with the proposed scenario along the Powder Arm as both the facultative and obligate riparian perennials are favored.

Thus, the more dynamic water elevation pattern of the proposed scenario is predicted to generally increase the elevational extent of riparian vegetation along the Brownlee Reservoir. This would correspondingly increase the vegetation groups except for the facultative riparian perennials. The model particularly predicts extent of occurrence rather than vegetation cover and we anticipate that cover may differ across the scenarios. Thus, our interpretations along the model output suggest that the proposed scenario would produce an elevationally broader band of riparian vegetation. However, the narrow band above the full pool elevation would be slightly denser with the ROR scenario. This broad interpretation is consistent with current patterns along Brownlee Reservoir versus the lower reservoirs.

Lower Reservoir Reaches

Of the three groups of study reaches (Brownlee Reservoir reaches, Lower reservoir reaches, Snake River), the model predicts that the lower reservoir reaches would differ the least across scenarios. Although the model predicts decreases with the proposed scenario for the main Oxbow Reservoir and for the main Hells Canyon Reservoir (Table 6.1.), as discussed in Chapter 3, the predicted effects would involve the vegetation zone just above full pool. Many plant types will occupy this zone and the ruderal annuals would generally be less competitive in this environment. Consequently, this model prediction probably exaggerates the future pattern and difference relative to this vegetation group.

The model predicts contrasting effects of the two scenarios on the riparian perennials along the Oxbow Reservoir reaches (Table 6.1.). The model predicts decreased facultative riparian perennials but slightly increased obligate riparian perennials with the proposed scenario. As described in Chapter 3, these differences would reflect two contrasting hydrologic changes. With the proposed scenario, the perennials would extend further downwards along the elevational profile but those at the upper end of the riparian zone would be less favored. Overall, the model predicts a slight reduction in the extent of riparian perennials with the proposed scenario but the quantitative extent predicted for the Hells Canyon (main) Reservoir is probably inflated due to limited sampling (Table 6.1.).

Comparison of Vegetation Groups across Study Reaches

The nature of the predicted differences in the vegetation groups across the two water management scenarios can also be reviewed by comparing spatial and temporal patterns across the seven study reaches. This comparison utilizes ‘cross-hair’ plots that were introduced in Chapter 3 with the x-axis indicating elevational extent and the y-axis representing duration of establishment (Figure 6.1.). Higher position on the y-axis represents earlier and/or more regular recruitment during the 110-year model run.

Facultative Riparian Annuals

The predicted patterns of facultative riparian annuals across the two scenarios and seven study reaches are presented in Figure 6.1. As shown, the model predicts two differences across the scenarios relative to this vegetation group. Along the three Brownlee Reservoir reaches (BH, BM, BP), the proposed scenario would produce a slight shift downward in elevation, but this would be associated with less regular establishment. This would produce a slight net increase in this vegetation group.

The second difference relative to the facultative riparian annuals would involve more regular recruitment with the proposed versus ROR scenario (Figure 6.1.). This difference would also slightly increase the overall extent of the facultative riparian annuals with the proposed scenario.

Facultative Riparian Perennials

The model predicts minimal differences among facultative riparian perennials across the two scenarios. Very minor differences are predicted for each of the seven reaches, even with the expanded time scale shown in Figure 6.2.

Hydrophytes

Like the obligate riparian vegetation groups, the hydrophytes represent a vegetation group that is distinctively linked to riparian and other wetland areas. The model predicts slight differences in hydrophytes along the Brownlee reservoir reaches with the slight downslope extension with the proposed scenario. Patterns along the lower reservoirs are predicted to be similar under the two scenarios.

The greatest difference in hydrophyte distribution is predicted for the Snake River reach (Figure 6.3.). The model predicts that the proposed scenario would produce a downward extension of this vegetation group as well as producing slightly earlier and/or more regular recruitment over the modeling period. Consequently the model predicts an increase in this vegetation group with the proposed scenario.

Obligate Riparian Annuals

The model predicts minimal difference in the obligate riparian annuals across the two scenarios (Figure 6.4.). This is consistently the case for the seven study reaches with the greatest predicted difference occurring along the Powder River Arm of the Brownlee Reservoir.

Obligate Riparian Perennials

Along with the facultative riparian perennials, obligate riparian perennials significantly contribute to habitat structure along the Hells Canyon corridor. The model predicts a slight increase in this vegetation group along the Snake River although that prediction (discussed in Chapter 3) is minimized in the summary plot of Figure 6.5.

Relative to the obligate riparian perennials along other reaches, the model predicts slight elevational extensions in distribution along the Brownlee Reservoir, particularly for the Powder Arm (Figure 6.5.).

Ruderal Annuals

Ruderal annuals represent the vegetation group that will be most affected by the operation scenario (Figure 6.6.). In particular, there would be major downward extensions in this vegetation group accompanying the draw-down of Brownlee Reservoir with the proposed scenario. This plant group includes many weedy species that provide limited vegetation structure and subsequently, limited wildlife habitat. This difference across operations scenarios is not only relevant to the modeling of wildlife habitat but is also important relative to the dispersal and proliferation of invasive exotic plants, including noxious species.

Conclusion and Recommendations

As predicted by the model and also consistent with interpretations of historical changes in riparian vegetation, we consider that the two different water management scenarios would have slight to moderate impacts on different riparian vegetation groups and corresponding plant communities. In general, the proposed scenario would increase the elevational extent of some vegetation groups, particularly with the downward expansion of some plant groups along the reservoir shorelines. Conversely, the more constant water elevation of the ROR scenario would produce more dense bands of some vegetation types along the fringe above the full pool position of reservoir reaches.

The model is intended to predict vegetation distribution both in terms of elevational occurrence and proportional representation in areal units across the elevational profile. However, due to the lack of consideration for competition between species, the model predicts that various life forms will occupy a given elevation band but does not predict the relative vegetation abundance (i.e., proportional cover) within these areal units (quadrats). Throughout Chapter 3 we have interpreted the model output relative to likely impact due to competition. In general, this consideration diminishes the difference across the two scenarios. Thus, we anticipate that the

proposed scenario would increase the elevational extent of most vegetation groups but in contrast, the ROR scenario would favor denser vegetation within the narrower riparian band.

Relative to the river riparian zone, some of the same interpretations apply. The model generally predicts that the proposed scenario would increase the extent of some of the vegetation groups; particularly, hydrophytes and obligate riparian perennials. However, the predicted zone of increase is primarily at elevations from about 1 to 3 m above the mean annual water level that will be the most extensive band for riparian vegetation. With potential competitive interactions, it is likely that that elevational band would be rapidly colonized by vegetation and consequently the differences across the two scenarios would be diminished.

Also with respect to the Snake River riparian zone, an intuitive hypothesis would be that the natural flow regime would be most ideal for riparian vegetation. We have observed that this is not the case for obligate riparian plants, such as cottonwoods and willows. For those plants, the natural flow regime is suitable but not optimal for establishment, growth and survival. Following from this principal, restoration flows might not mimic natural flows, but instead deliver water stage patterns that satisfy life-history needs. This strategy can be applied as compensation for other impacts or unavoidable artificial aspects of instream flow and sediment transport.

A second consideration also applies. The Snake River and its tributaries are extensively dammed and diverted upstream of the Hells Canyon complex and thus, the inflow hydrology is no longer natural. The alluvial sediment regime has undergone major alteration and further, many exotic plants have encroached and become 'naturalized' along the corridor. Thus the vision of a natural landscape demands cautious interpretation. The river and reservoirs of the Hells Canyon Corridor include a combination of natural and artificial elements that combine to create the current landscapes. The vegetation modeling approach was undertaken to predict overall changes in both native and exotic plant species along the natural (river) and artificial landscapes (reservoir). With this complexity, the simple prediction that the 'natural' flow regime is 'best' deserves careful evaluation.

The run-of-river scenario might be viewed as a more natural flow regime for the Hells Canyon reach of the Snake River than the proposed scenario. The modeling results, however, actually predict increased riparian vegetation with the proposed scenario but some of the gains and particularly the expansion of the ruderal annuals would not be considered as either natural or especially favorable relative to conserving the remaining natural attributes of the corridor.

Although the model analyses might be interpreted to favor the proposed scenario, we would not forward this as an ecologically based recommendation. The vegetation modeling suggests that either the proposed or ROR management scenario will largely sustain the current vegetation patterns along the corridor. There were not dramatic differences in riparian vegetation across the two scenarios and those differences that are likely to occur would probably result in only modest differences in wildlife habitat.

6.4. Noxious and Invasive Plant Species Responses to Hells Canyon Operations

Chapter 4 of the report analyzed the probable impacts of different flow scenarios on noxious and invasive weeds. Twenty problem plant species were assessed through a combination of HC_REM modeling and considerations of life history traits. Analyses of noxious and invasive plants considered two aspects, (1) dispersal and (2) proliferation. For plants that do not yet currently occur along some reaches, and particularly along the river reach downstream of Hells Canyon Dam, dispersal was especially important. For plants that exist within a reach, proliferation was more relevant. Proliferation was modeled through the HC_REM approach and the patterns previously discussed in Section 6.3 generally apply. Predictions related to dispersal considered hydrochory, water-based dispersal of seeds and/or clonal fragments and then subsequent water conditions that influence establishment and survival of new seedlings and/or clonal plants.

Of the twenty noxious and invasive species, these comparative analyses indicated relatively similar conditions for about 15 species across scenarios. These plants are often promoted by various human disturbances and will probably be relatively unaffected by the water management pattern.

The HC_REM analysis predicts that ruderal annuals will increase under the proposed scenario versus the run-of-river scenario. This prediction is probably relevant for the noxious weed, puncture vine, *Tribulus terrestris*, and also for various other exotic ruderal annuals that are not considered 'noxious'. These plants would annually colonize the draw-down zone along Brownlee Reservoir and would subsequently increase in number and also progressively expand downstream along that reservoir. However, as a group the ruderal annuals tend to be opportunists that colonize barren sites created by various human and natural disturbances. These plants are already widespread along the Hells Canyon Corridor and particularly occur in zones associated with road and recreational disturbance as well as fluvial disturbance.

The analyses predict that at least four noxious and/or invasive weeds would be impeded in downstream expansion by the proposed operating scenario. Thus, white-top (*Cardaria draba* and other *Cardaria* species), leafy spurge (*Euphorbia esula*), Russian olive (*Eleagnus angustifolia*), and salt cedar (*Tamarix ramosissima* and other *Tamarix* species and hybrids) are currently restricted to the upstream reaches of the study corridor. The downstream expansion of these invasive weeds has probably been substantially impeded by the historic annual draw-down of Brownlee Reservoir. Seedlings or clonal plants would be established below full pool and with subsequent draw-down those plants would suffer from desiccation stress. Those plants that survived this drought-stress would subsequently be flooded with the filling of Brownlee Reservoir and experience inundation stress. The combination of drought stress and inundation stress would eliminate the vast majority of these encroaching plants. Occasionally, individuals of these invasive weeds would become established at locations such as near tributary inflows that would be survivable and although impeded, these plants will probably eventually extend downstream beyond Brownlee Reservoir. Additionally, there are alternate propagule sources in addition to the inputs from the Weiser reach and the Powder River and these would also enable expansion of these invasive plants.

Relative to the ecology of the riparian zone downstream of Hells Canyon Dam, it is probable that the continued restriction of some potentially catastrophic invasive weeds could be very significant. The proposed scenario would continue to impose annual draw-down of Brownlee Reservoir that should continue to impede the downstream expansion of salt cedar and other plants. This would provide a substantial ecological benefit associated with the proposed scenario compared to the ROR scenario.

6.5. Threatened and Endangered Plant Species Response to Hells Canyon Operations

On the basis of several investigations, we conclude that rare plant populations will not be significantly impacted by either of the two flow scenarios. We base this conclusion on the combination of 1) extensive field inventories of rare plant populations within the study corridor (Krichbaum 2000, Holmstead 2001), and 2) more intensive sampling of Schweinitz flatsedge (*Cyperus schweinitzii*), a rare species along the Hells Canyon Reach of the Snake River. Only in some limited cases would additional studies of the life history, ecology and distributional patterns of select species be warranted. Almost all of the rare plants observed in the study corridor were found in upland areas adjacent to riparian zones. Schweinitz flatsedge, porcupine sedge and wood sage grow at elevations where annual peak flows occasionally inundate isolated, local populations of these rare species. However, these populations are regularly exposed to such flow conditions. Further, annual peak flows do not differ between the two flow scenarios. Therefore we anticipate only minimal impacts, if any at all, to local populations of rare plants within the study corridor.

Table 6.1. Percentage differences among quadrats occupied by each vegetation group in the proposed scenario versus the ROR scenario. Positive or negative values indicate more or less vegetation (respectively) in the proposed scenario. For the reasons discussed in the text, Snake River quadrats at elevations >9 m or < -1 m from the mean annual water level were omitted from this analysis.

| Study Reach | (FRA) Facultative Riparian Annuals | (FRP) Facultative Riparian Perennials | (HYD) Hydrophytes | (ORA) Obligate Riparian Annuals | (ORP) Obligate Riparian Perennials | (RA) Ruderal Annuals |
|---|---|--|----------------------|--|---|----------------------------|
| Brownlee Reservoir reaches: | | | | | | |
| (BH) Brownlee Reservoir– Headwater | 10.7 | -12.0 | 66.0 ³ | 8.2 | 11.9 | 329.9 |
| (BM) Brownlee–Main | 11.2 | -26.7 | 46.2 ³ | 8.6 | 6.3 | 198.9 |
| (BP) Brownlee Reservoir– Powder River Arm | 21.2 | 12.0 | 62.9 ³ | 13.0 | 15.0 | 598.7 |
| Lower reservoir reaches: | | | | | | |
| (OM) Oxbow Reservoir–Main | -12.1 | -10.5 | 0.0 | 0.0 | 16.4 | -26.4 ¹ |
| (OB) Hells Canyon Reservoir– Oxbow Bypass | 0.0 | -9.0 | 0.0 | 4.3 | 3.1 | 3.7 |
| (HM) Hells Canyon Reservoir– Main | 26.6 ² | -32.4 ² | 0.0 | 0.0 | 7.8 | -21.2 ¹ |
| (SN) Snake River | 0.4 | 2.2 | 24.7 | 2.2 | 9.0 | 0.3 |

¹ As discussed in Chapter 3, due to the lack of competition in the model, these values are probably exaggerated.

² As discussed in Chapter 3, these predictions result from two particular elevations with minimal sampling and unique plant distributions. Other than these spurious differences the two facultative riparian plant groups were quite similar for this reach.

³ As discussed in Chapter 3, HC_REM predictions for hydrophytes were somewhat variable and contrary to observed field distributions, thus these predictions should be viewed with caution.

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Figure 6.1. Average elevation versus average number of years since establishment of all quadrats occupied by Facultative Riparian Annuals (FRA) at year 110 for each scenario (bars indicate +/- one standard deviation from the mean).

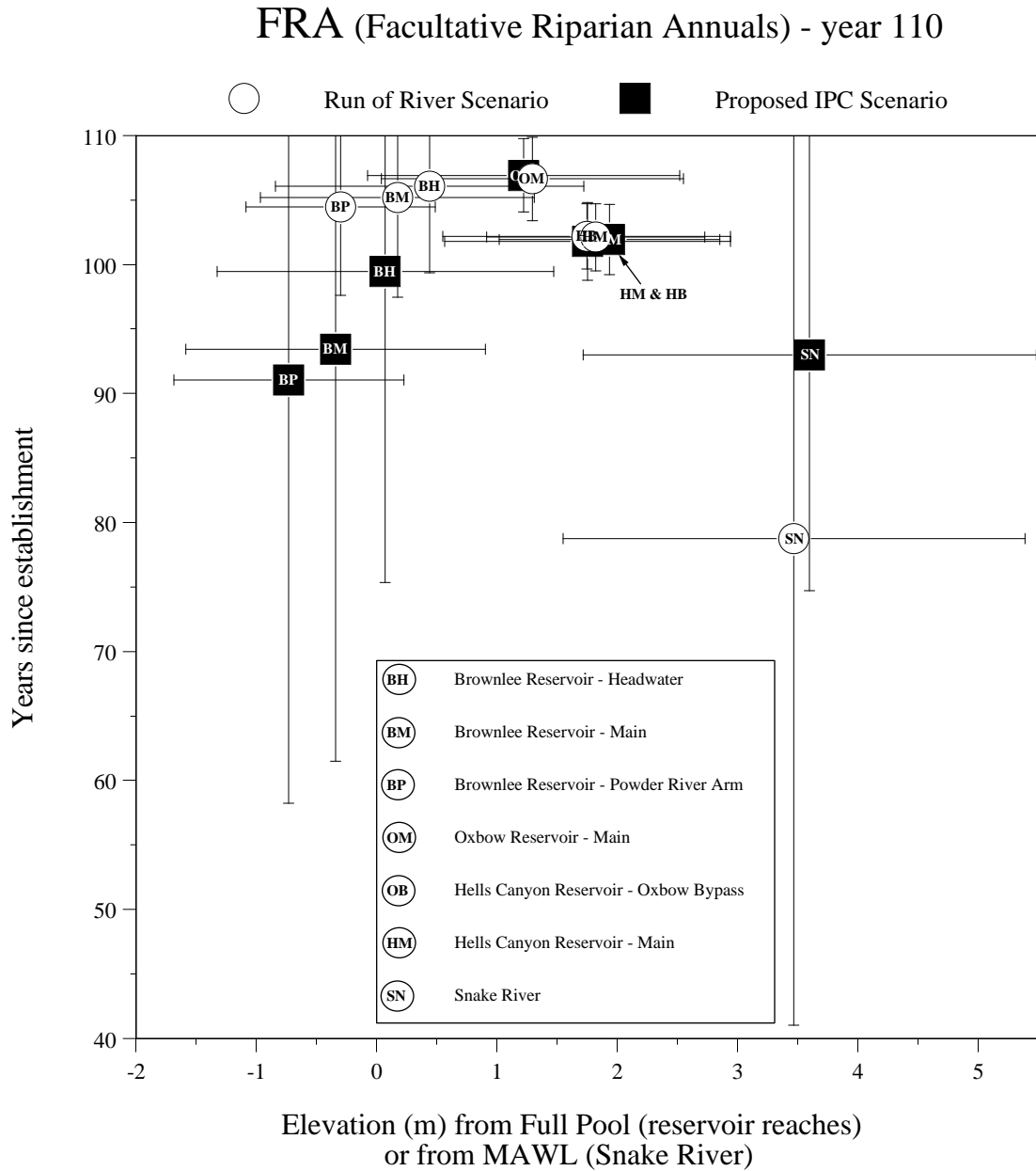


Figure 6.2. Average elevation versus average number of years since establishment of all quadrats occupied by Facultative Riparian Perennials (FRP) at year 110 for each scenario (bars indicate +/- one standard deviation from the mean).

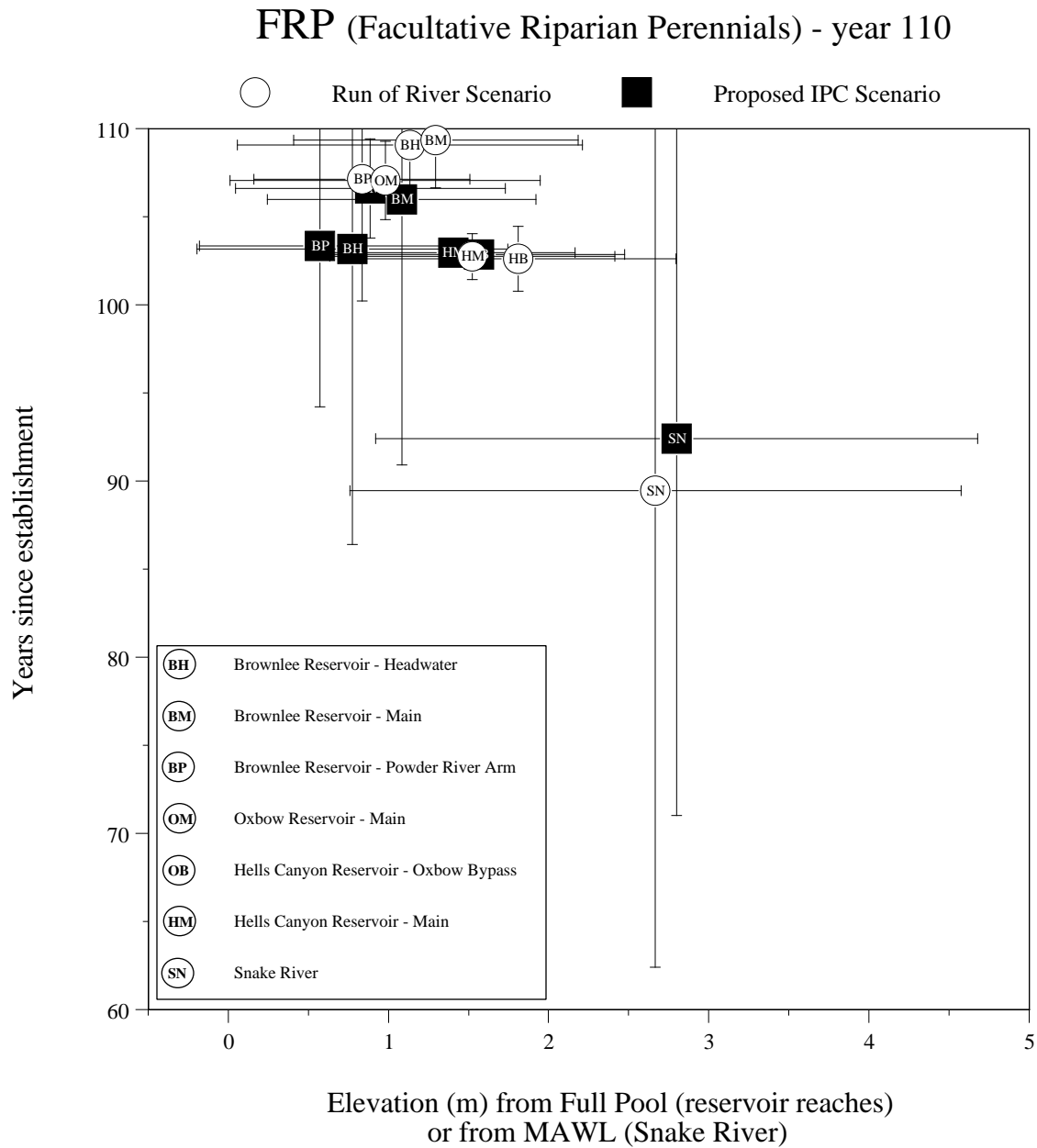


Figure 6.3. Average elevation versus average number of years since establishment of all quadrats occupied by Hydrophytes (HYD) at year 110 for each scenario (bars indicate +/- one standard deviation from the mean).

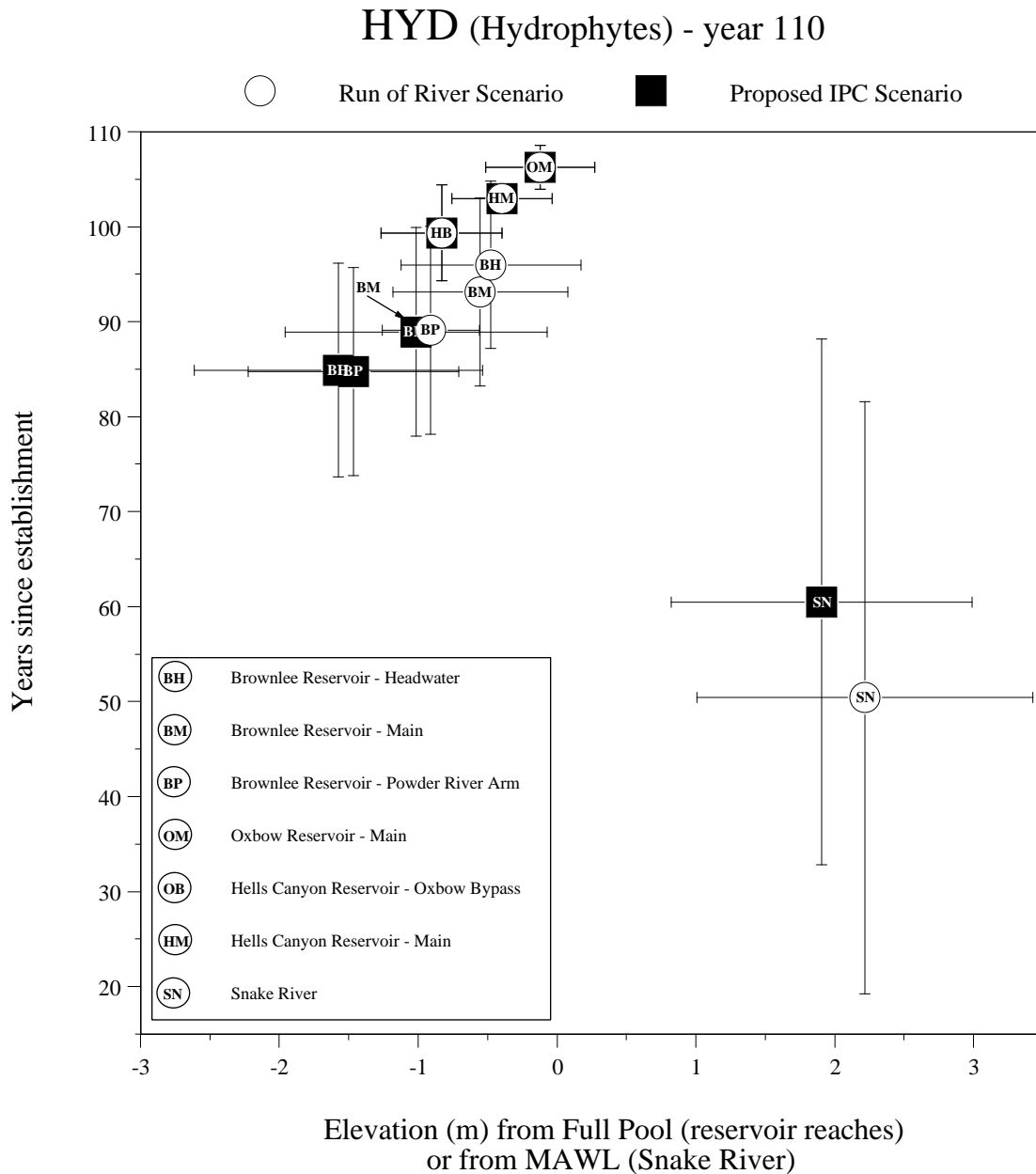


Figure 6.4. Average elevation versus average number of years since establishment of all quadrats occupied by Obligate Riparian Annuals (ORA) at year 110 for each scenario (bars indicate +/- one standard deviation from the mean).

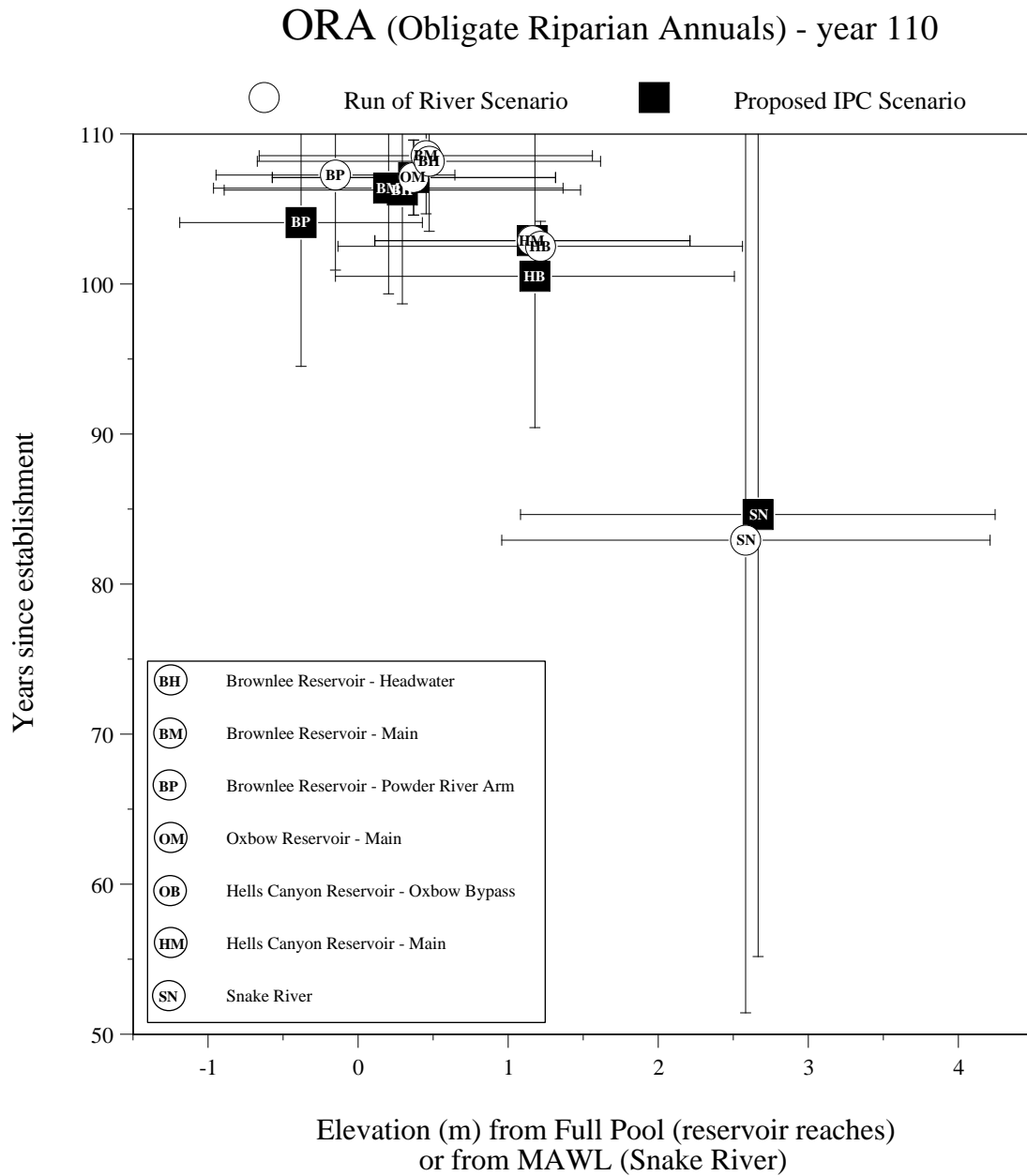


Figure 6.5. Average elevation versus average number of years since establishment of all quadrats occupied by Obligate Riparian Perennials (ORP) at year 110 for each scenario (bars indicate +/- one standard deviation from the mean). Study reach abbreviations are the same as defined in Figure 6.4.

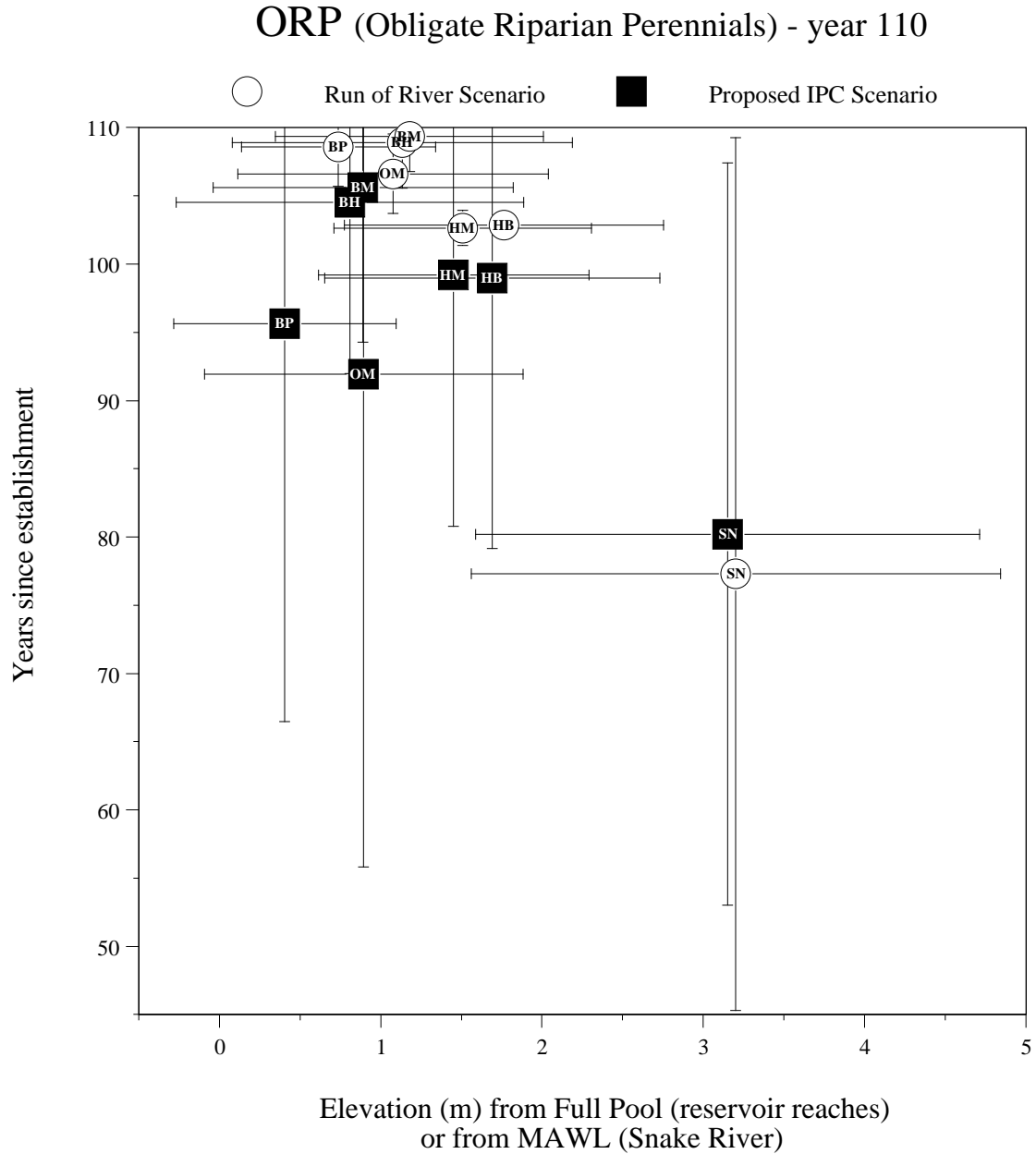
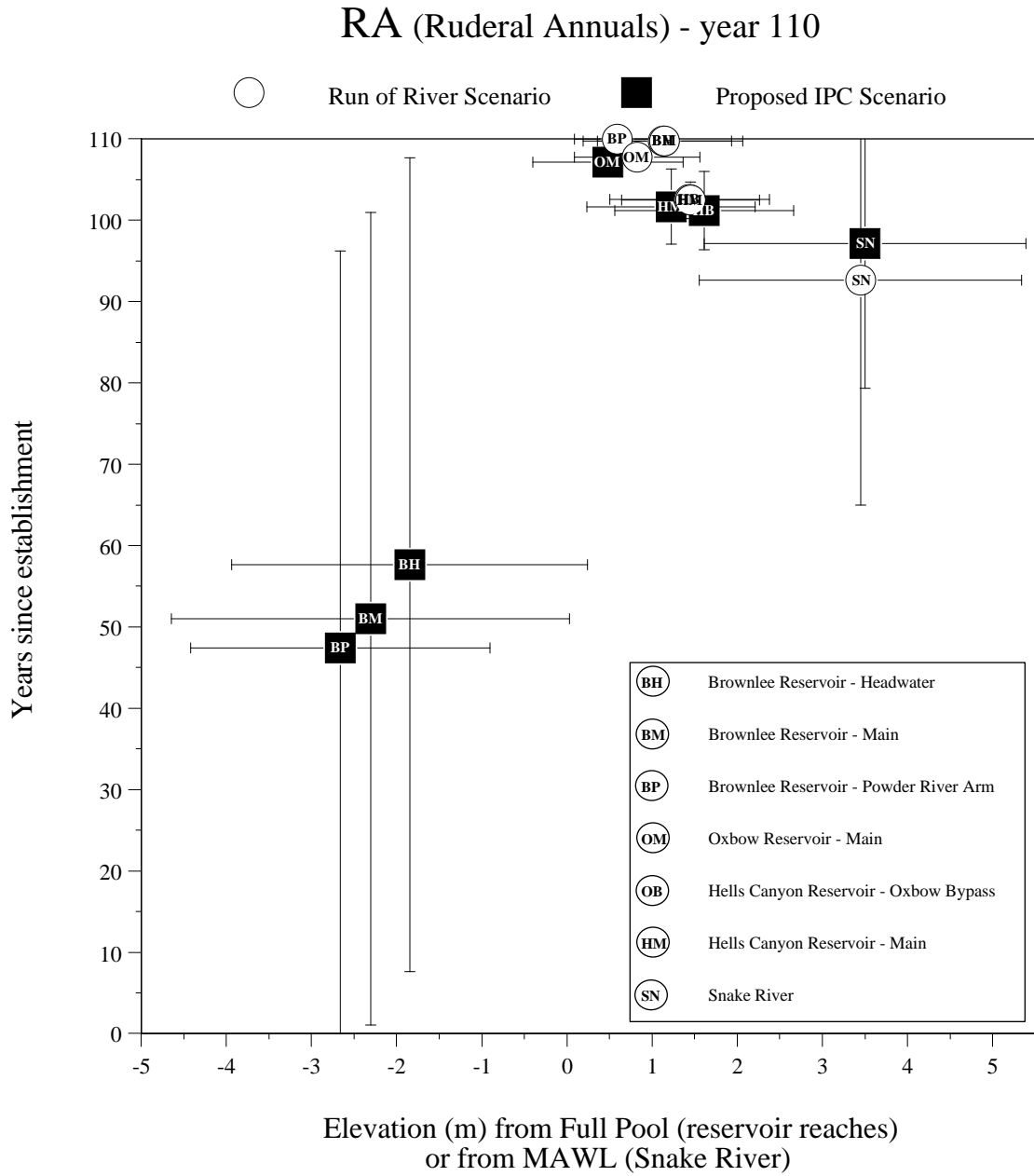


Figure 6.6. Average elevation versus average number of years since establishment of all quadrats occupied by Ruderal Annuals (RA) at year 110 for each scenario (bars indicate +/- one standard deviation from the mean).



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