# FINAL SUPPLEMENTAL ENVIRONMENTAL ASSESSMENT

## Río Puerto Nuevo Flood Control Project

San Juan, Puerto Rico

January 2026

# APPENDIX C: WETLAND MITIGATION AND CONTINGENCY PLAN

U.S. Army Corps of Engineers
Caribbean District

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# Wetland Mitigation and Contingency Plan

Río Puerto Nuevo Flood Control Project

San Juan, Puerto Rico

## I. Background

This document outlines the Wetland Mitigation and Contingency Plan for the Preferred Alternative, Alternative 4, for the Rio Puerto Nuevo Flood Control Project (RPN Project) 2025 Supplemental Environmental Assessment (SEA). The purpose of this plan is to detail the strategy for determining the type and quantity of compensatory mitigation proposed to offset the unavoidable impacts to wetlands resulting from the implementation of the proposed project, as identified in this SEA.

In 2014 a compensatory wetland mitigation project was completed for the total RPN Project wetland impacts. The mitigation involved planting 28 acres of estuarine wetlands along the Margarita channel right-of-way within the Puerto Nuevo River. These were 28 acres of compensatory mitigation for the 20 acres of wetland areas to be impacted by the RPN Project. Initially, the RPN Project impact on wetlands (mangroves and mud flats) was estimated at 33.3 acres, which was reduced by 13.3 acres to a total of 20 acres due to changes to the RPN Project's footprint.

Changes in regulations since the project was initially approved have added restrictions for material placement on the material management areas (MMA) previously identified for the RPN Project. This SEA evaluation for a suitable MMA has concluded that the Preferred Alternative presented in the SEA, would unavoidably impact wetland resources. Specifically, 11.4 acres of estuarine wetlands to be impacted by placement of fill material. This plan details how those impacts will be mitigated to achieve no net loss of wetland function and value.

## II. Objectives

The primary objective of this Wetland Mitigation and Contingency Plan is to offset the unavoidable losses to wetland habitat resulting from the proposed action for the RPN Project. Ecological model results define project impacts, and mitigation planning objectives reflect these losses. Specifically, the plan aims to compensate for impacts by restoring and enhancing estuarine wetland habitats, ensuring the continued provision of ecological functions and services within the watershed. The objectives are to restore and enhance wetland functions to a level equivalent to, or exceeding, those expected to be lost due to project construction within a 10-year timeframe.

## III. Mitigation Type and Site Selection

Compensatory mitigation for unavoidable impacts to aquatic resources, in this case tidal wetlands, can be accomplished through a series of options. For DA permit applications, a hierarchical strategy has been established for selecting the type and location of compensatory mitigation (40 CFR Part 230.93(b)). Mitigation bank credits is the preferred option with in-lieu fee programs credits as the second option preferred. Both of these help to reduce the risk of failure for the mitigation projects as they consolidate resources and involve more scientific expertise and financial planning. The third option is the permittee-responsible mitigation in which the permittee constructs a project to provide compensatory mitigation for the authorized activities. This permittee-responsible mitigation in turn is divided into three types: the watershed approach, the in-kind and on-site mitigation, and the out-of-kind and/or off-site mitigation.

Currently in Puerto Rico, mitigation banks or in-lieu fee programs for compensatory mitigation are not available. However, if they become available in the near future, they may be evaluated for consideration. For this project, the Corps is proposing in-kind and on-site mitigation, which is considered the most viable option for this project and preferred over the out-of-kind and/or off-site mitigation. The watershed approach was not considered appropriate and practicable as a potential compensatory mitigation strategy for the losses in aquatic resources. This was due to the lack of an appropriate watershed plan and the absence of identified rare, unique, or high-quality aquatic resources within the watershed that could have informed the strategic selection for ecological functions.

Of the areas seen in Figure 1, some of the undeveloped sites are not available due to current or past usage such as the closed San Juan landfill, La Chuleta MMA, the 2014 RPN Project mitigation area and another mitigation area known as the Rupert Armstrong Farm, which has a conservation easement. These reduce available sites for enhancement, restoration and/or establishment.

Figure 1. Usage of undeveloped areas within the brackish waters of the RPN watershed.

Two in-site areas were identified within the RPN watershed as viable for an in-kind compensatory mitigation; the wetland area northwest of the J.F. Kennedy Expressway and southwest of the Bechara channel, and the upland and wetland area southeast of the proposed Bechara MMA (Figure 2).

The wetland area northwest of the Kennedy Expressway is approximately 22-acre of wetlands. This amount of acreage is not enough for the required compensatory mitigation by enhancement, using the Average Annual Habitat Unit (AAHU) calculating method. This was assuming that the wetland conditions and Unified Mitigation Assessment Method (UMAM) evaluation for those 22 acres are similar to the 11.4 acres of wetlands to be impacted.

The area southeast of the proposed Bechara MMA is partitioned by electric power transmission lines. The section between the Bechara channel and the power lines utility easement is about 10 acres of filled upland and about 20 acres of degraded wetlands. The section between the power lines utility easement and the San Juan landfill is about 4 acres of filled upland and about 5 acres of wetland. Due to the power lines easement, these two areas would not be connected, so they would essentially be designed, restored/enhanced and manage independently. Compensatory mitigation by restoring 4 acres and enhancing 5 acres would not suffice to offset the project's expected wetland impacts. In addition, compensatory mitigation on this section, would represent risks associated with working in close proximity to the landfill. There are also benefits with retaining this area as is, because it would continue to provide access to the electric power utility agency. Based on these considerations, the compensatory mitigation will be focused on the larger area between the Bechara channel and the power lines. Performing restoration and enhancement within the larger section between the Bechara channel and the power lines, the approximate 10-acre upland and 20-acre wetland area, would suffice to offset the project's anticipated impacts and result in no net loss of wetland resources.

Figure 2. Available acreage for wetland restoration and enhancement within the brackish waters of the RPN watershed.

Based on practicability and ecological suitability, the selected strategy is in-kind, on-site and within watershed restoration and enhancement of mangrove wetland habitat southeast of the proposed Bechara MMA. This approach maximizes the potential for successful mitigation within the affected watershed.

## IV. Mitigation Site Protection Instrument

The compensatory mitigation lands are located within the state/federal floodway within the Project construction limits. These lands are within the authorized project limits and are owned by the Government of Puerto Rico. The Department of Natural and Environmental Resources (DNER), as the non-Federal sponsor, will acquire the necessary lands and certify such for the Project.

## V. Baseline Information

The Puerto Nuevo River basin was historically dominated by wetlands; however, by the end of the 1940s, a significant portion of wetlands had been lost (Figure 3). The brackish water conditions necessary for estuarine wetland habitat are largely restricted to areas of the project closer to San Juan Bay. Consequently, opportunities for in-kind, on-site, and in-watershed compensatory mitigation within the Puerto Nuevo River watershed are limited due to ongoing development.

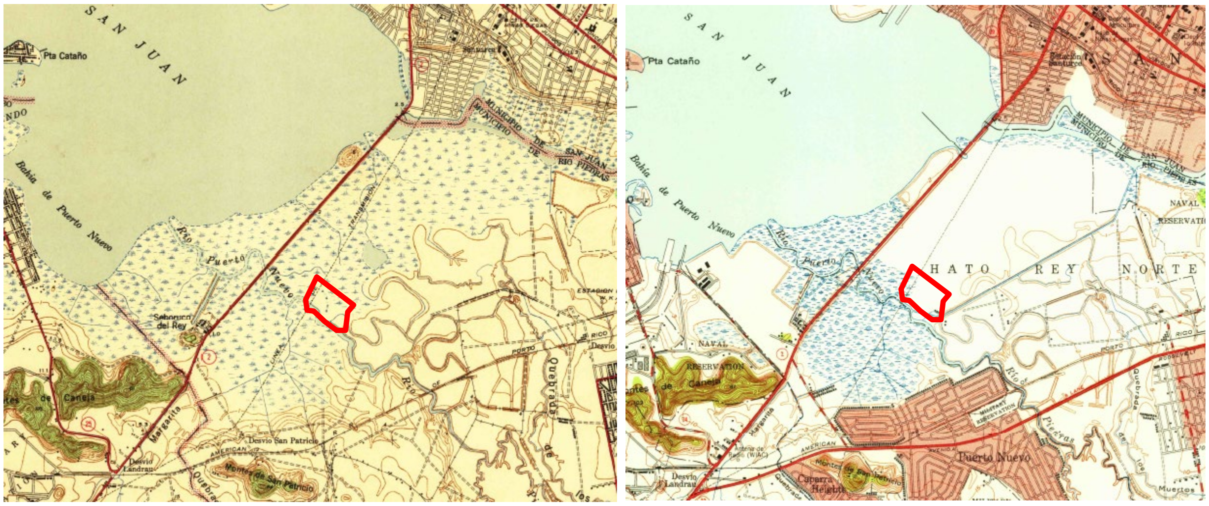

Figure 3. U.S. Geological Survey (USGS) 1940 and 1949 maps of the Puerto Nuevo area in San Juan, PR. The red polygon is the approximate location of the compensatory mitigation area.

The area identified for potential compensatory mitigation was partially filled in the mid-1900s (Figure 4), and subsequently maintained as an upland area by the Municipality of San Juan. Currently, this filled portion is vegetated by a monoculture of grass, offering limited ecological value.

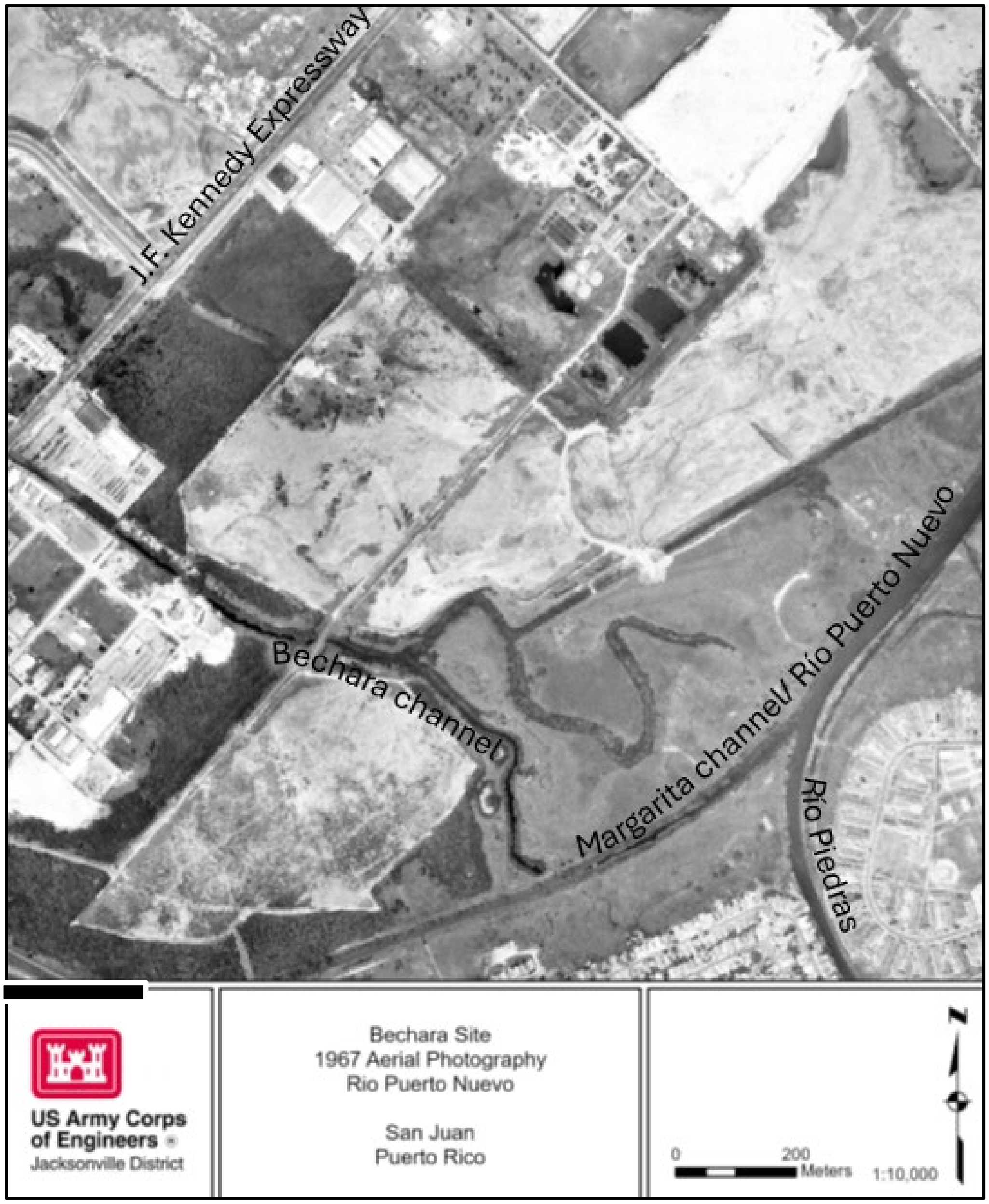

Figure 4. Filled material areas within the Bechara site (1967).

The wetland portion contains estuarine resources that provide habitat for various species and contribute to water quality. Hydrology is a critical factor influencing the ecological health of wetland systems. The wetland area proposed for compensatory mitigation exhibits disturbed hydrology, which is a likely cause of its degradation. This altered hydrology is visually represented in Figure 5, utilizing a U.S. Geological Survey (USGS) Digital Elevation Model (DEM) to highlight shallow areas within the wetland channels and therefore, inadequate hydrological connection to the Bechara channel or the Río Puerto Nuevo. Hydrological connectivity enhancement would facilitate the natural establishment of mangrove propagules and improve soil characteristics, thereby increasing organic carbon storage. Rehabilitating the hydrology would also benefit aquatic, bird, and wildlife habitats.

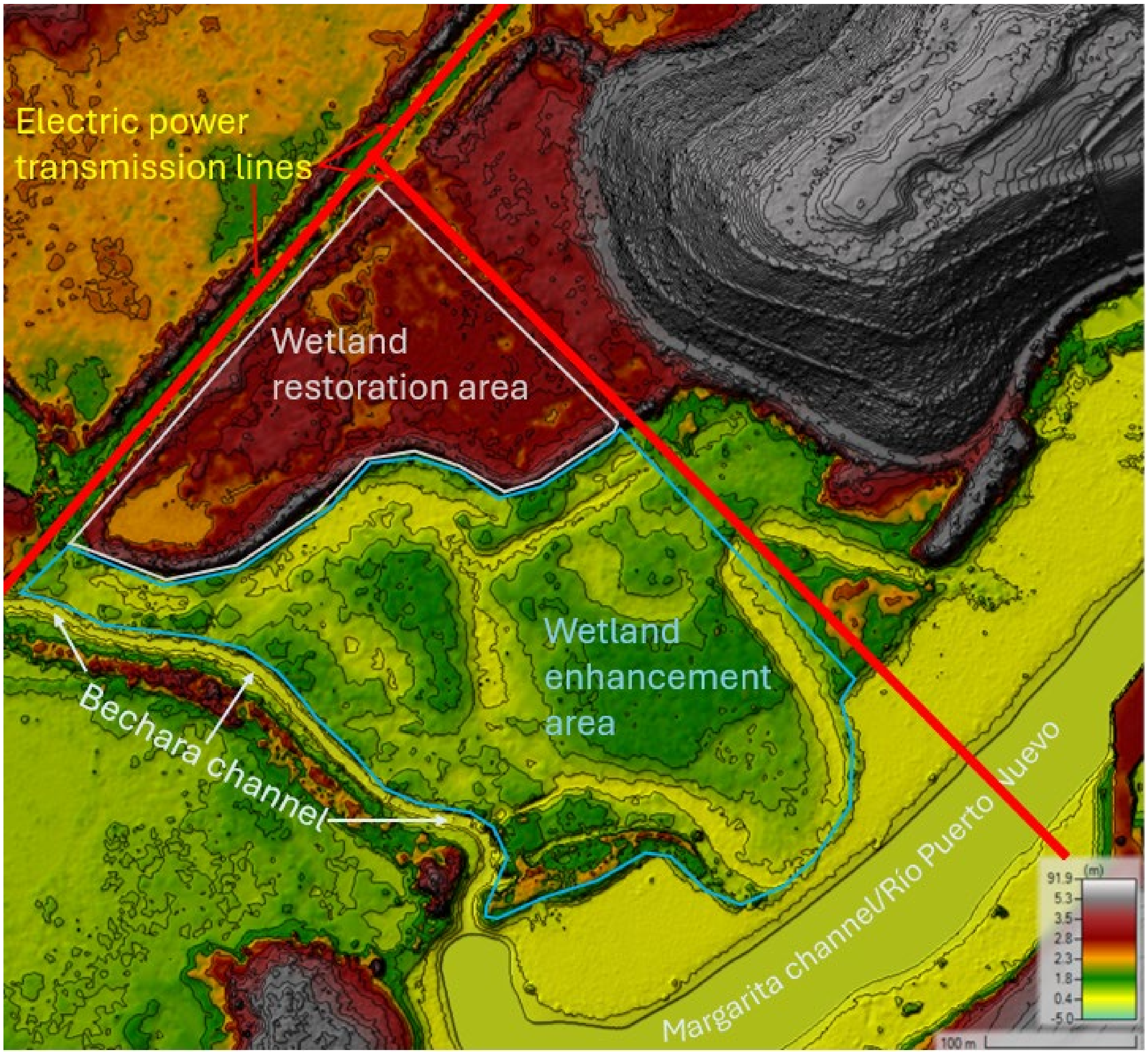

Figure 5. U.S. Geological Survey, Digital Elevation Model.

Wetland enhancement in this area would also include the removal of invasive species and the potential reestablishment of native mangrove communities. Commercial and industrial areas are particularly susceptible to invasive species due to increased human activities such as trade, transport, and shipping, which facilitate spreading through infrastructure and establishment in disturbed ecosystems. Flora surveys conducted for the proposed Bechara MMA site, located northwest of the proposed wetland mitigation area, identify a significant presence of invasive exotic species; approximately 32 percent of the plant species identified were considered invasive (Water and Air Research, Inc. 2023; Appendix D).

In summary, the proposed mitigation area represents a degraded estuarine wetland with compromised hydrology with a high potential for invasive species presence. Restoration efforts focused on hydrological rehabilitation that include invasive species removal are crucial to improving the ecological function of this area and achieving successful compensatory mitigation for unavoidable project impacts.

# VI. Compensatory Wetland Mitigation Functional Analysis and Mitigation Requirements

The UMAM was used to determine a Habitat Suitability Index (HSI) score for the wetlands to be impacted and restored. This method evaluates three functional assessment categories: Location and Landscape Support, Water Environment, and Community Structure (Vegetation). For each category between 8 and 12 attributes are considered to determine that category's score. Afterwards, the scores for each of the categories are added and the value is divided by 30 to yield a number between 0 and 1 (Bardi *et al*., n.d.). This number becomes the Habitat Suitability Index (HSI) on the calculations of the Habitat Units (HUs) and the AAHU for the Future without Project (FWOP), Future with Project (FWP) and the AAHUs Net Change or gains/losses.

The UMAM is well suited for evaluating a suite of impact and potential mitigation sites, including the preservation, enhancement, restoration, and creation of wetlands, as well as the evaluation and use of mitigation sites, and it provides a framework for standardized wetland assessment methodology. This method was approved for use in Puerto Rico by U.S. Army Corps of Engineers (Corps) National Ecosystem Restoration Planning Center of Expertise (ECO-PCX) on June 9, 2020.

The HUs and AAHUs calculations used were developed and published by U.S. Fish and Wildlife Service (USFWS) Division of Ecological Services in their Habitat Evaluation Procedures (HEP) (USFWS 1980) (HEP excerpt in Appendix A).

The wetland areas to be impacted, restored and enhanced were evaluated using the method and procedure mentioned above. A field site visit was done on January 22, 2025, for the UMAM evaluation of the wetlands to be impacted and restored. The evaluation combined the assessments performed by staff members of USFWS Caribbean Ecological Services Field Office, P.R. Department of Environmental and Natural Resources (DNER), and the U.S. Army Corps of Engineers, Caribbean District. For the wetland enhancement area, the USGS DEM was used to identify the lack of hydrological connectivity, and the evaluation score of the impacted wetland area was use as proxy.

The timeframe of analysis used for the AAHU calculations is 50 years. The impacted wetlands received a HSI score of 0.73 and during the 50-year timeframe of analysis, as described in Section 5.7 of the SEA, their conditions are expected to degrade further. The proposed project would unavoidably cause the loss 11.4 acres of wetlands. The HUs and AAHUs calculations based on the UMAM evaluation, 50-year timeframe and Future with and without project, will result in the loss of 6.94 AAHUs of wetlands, which would need to be offset by compensatory mitigation.

Compensatory mitigation for the losses of 6.94 AAHUs of wetland through restoration exclusively would require more than 10 acres. As mentioned previously, the area for restoration has approximately 10 acres and the agencies' UMAM evaluations provided a HSI score of 0.13. The AAHUs calculations of restoring 10 acres resulted in

6.34 AAHUs of compensatory mitigation, leaving the need for an additional 0.6 AAHUs. Similarly, using the same HSI and Target Years parameters, restoring 9 acres of mangrove wetland habitat can yield 5.70 AAHUs. These are assuming that mitigation restoration success is achieved within 5 years of construction and its state will remain at or continue to improve.

Compensatory wetland mitigation through enhancement only with a HSI of 0.73, would require more than 100 acres of wetlands. The enhancement area has approximately 20 acres and enhancement of 9 acres (0.60 AAHUs) combined with the 10 acres of restoration, would be the amount required to comply with the total compensatory mitigation of 6.94 AAHUs. Likewise, enhancement of 19 acres can provide 1.26 AAHUs, which combined with the 5.70 AAHUs from restoring 9 acres, would also meet the requirement for the 6.94 AAHUs needed for compensatory mitigation. These calculations assume that the mitigation success timeframe and continuing conditions will be the same to the restoration area.

| Wetland area | Future with Project (FWP)/Future without Project (FWOP) | Target Year | Acreage | HSI | Total HUs | Cumulative HUs | AAHUs | AAHUs Net Change (FWP-FWOP) |
|---|---|---|---|---|---|---|---|---|
| Impact | FWP | 0 | 11.4 | 0.73 | 8.36 | | | |
| | FWP | 1-50 | 11.4 | 0.00 | 0.00 | 4.18 | 0.08 | |
| | FWOP | 0-50 | 11.4 | 0.73 | 8.36 | | | |
| | FWOP | 50 | 11.4 | 0.50 | 5.70 | 351.41 | 7.03 | -6.94 |
| Restore | FWP | 0-5 | 10 | 0.13 | 1.30 | | | |
| | FWP | 5-50 | 10 | 0.80 | 8.00 | 360.00 | 7.67 | |
| | FWOP | 0-50 | 10 | 0.13 | 1.33 | 66.50 | 1.33 | 6.34 |
| Enhance | FWP | 0-5 | 9 | 0.73 | 6.57 | | | |
| | FWP | 5-50 | 9 | 0.80 | 7.2 | 324.00 | 11.15 | |
| | FWOP | 0-50 | 9 | 0.73 | 6.57 | 328.50 | 10.22 | 0.60 |

Table 1. Habitat Units (HUs) and Average Annual Habitat Units (AAHUs) input and results for 10 acres of restoration and 9 acres of enhancement. (Note: A negative AAHUs Net Change value represents habitat loss, a positive AAHUs Net Change value represents habitat gain.)

Based on this analysis, the recommended plan for an in-kind, on-site, and in-watershed compensatory mitigation for no net loss of 6.94 AAHUs in wetlands involve:

- 10 acres of mangrove wetland habitat restoration (6.34 AAHUs) and,
- 9 acres of mangrove wetland habitat enhancement (0.60 AAHUs) or,

- 9 acres of mangrove wetland habitat restoration (5.70 AAHUs) and,
- 19 acres of mangrove wetland habitat enhancement (1.26 AAHUs).

## VII. Mitigation Work Plan

The mitigation work will involve the following activities:

- **Site Preparation:** Clearing of grass vegetation, and identified nuisance and invasive species, grading to establish appropriate elevations, and installation of erosion control measures.

- **Planting and seeding:** Planting and seeding of native mangrove species appropriate to the site conditions, along with associated species. There are three native mangrove species to the Island of Puerto Rico:

    - Red Mangrove (*Rhizophora mangle*), which tend to grow at sea level, by or close to the water's edge,
    - Black Mangrove (*Avicennia germinans*), grow slightly inland, landward to the red mangrove in the intertidal zone and,
    - White Mangrove (*Laguncularia racemosa*) typically occurs further inland and upland than the other two species, on the landward fringe of mangrove communities.

- **Hydrological Restoration:** Re-establishment of natural hydrological regimes through modifications to drainage patterns or the removal of obstructions. Hydrological features would be created for the restoration area in order to obtain the desired conditions for the mangrove species to be planted. Restoring hydrological channel connectivity to more natural dimensions and reducing or removing barriers to water flow through mechanical means.

- **Monitoring:** Implementation of a monitoring plan to track progress towards performance standards. Monitoring mangrove health through Biological, Physicochemical and Hydraulic indicators to guide any required adaptive management strategy to have a successful compensatory mitigation.

All work will be conducted in coordination with the DNER and other relevant resource agencies.

## VIII. Performance Standards

The ecological success criteria for mangrove wetland habitat are identified below. These criteria are based on a review of scientific literature (Rodríguez 2021, Teutli-Hernández 2021, Bosire 2008, Krauss 2008, Lewis 2005, Twilley & Rivera-Monroy 2005,) and are designed to ensure the mitigation project meets the planning objectives. The following table outlines the key performance standards:

| Criteria | Metric | Target | Time-period |
|---|---|---|---|
| **Hydraulic Conditions** | Hydroperiod | Consistent with natural tidal regime | Month 1 |
| **Physicochemical conditions** | Salinity | Consistent with mangrove species tolerance | Each monitoring event |
| | pH | 6.5-8.5 | Each monitoring event |
| | Soil redox | -200 to +100mV | Each monitoring event |
| | Dissolved Oxygen (DO) | > 2.0 mg/L | Each monitoring event |
| | Soil organic matter | 5-15% | 2 consecutive monitoring events |
| **Biological** | Mangrove cover | ≥ 40% cover | 2 consecutive years |
| | Mangrove planting survival | ≥ 80% survival | Year 1 |
| | Height | ≥ 20 cm, ≥ 70 cm | Year 1, Year 3 |
| | Stem diameter | ≥ 0.4 cm, ≥ 1 cm | Year 1, Year 3 |
| | Canopy width | ≥ 0.4 m | Year 3 |
| | Mangrove natural recruitment | ≥ 10% of total stems | 2 consecutive monitoring events |
| | Disease or Pests | ≤ 5% total affected | Each monitoring event |
| | Invasive and nuisance plant species | ≤ 5% total cover | Each monitoring event |
| | Estuarine wetland associated flora species | Document number of species present | Each monitoring event |

## IX. Monitoring Requirements

Monitoring will be conducted to assess progress towards achieving the performance standards for the wetland restoration and enhancement areas.

The following schedule will be followed for the restoration and enhancement areas:

- Monitoring before enhancement actions.
- Monitoring after the enhancement and the restoration actions, time-zeros.
- Monitoring every 4 months during the first year.
- Monitoring every 6 months during the second year.
- Monitoring annually from the third year and beyond.

Monitoring will focus on the following criteria:

- Hydroperiod
- Plant structure and composition
- Regeneration

The metric's target value during the time-period specified will be used to determine the success of the compensatory mitigation and weather adaptive management actions are needed. Metrics with a time-period of a Year number can be considered accomplished once the target value is achieved on the Year number stated or later. Not achieving the target value for the Year may trigger the need of adaptive management actions until the value is achieved. Metrics with consecutive periods such as years or events can be considered accomplished once the target value is achieved for the number of consecutive periods specified. The first time the target value is achieved, it will be considered as the first time-period for the necessary number of consecutive periods specified. If the second time-period does not meet the target value, adaptive management actions may be taken and a new first time-period would be established in order to achieve the number of consecutive periods specified and determine the metric as successful. Metrics with a time-period of 'Each monitoring event' are to be used as reference in determining if adaptive management actions are necessary. These metrics along with the Hydraulic Conditions are not metrics to determined mitigation success, but to guide and facilitate a successful compensatory mitigation.

Monitoring of metrics with a time-period of a Year number or consecutive periods are considered independent from each other, so if one metric does not achieve the target value, it does not negate another metric achieving the target. Once that metric is achieved it can be determined as successful and further monitoring for that metric is not required.

Compensatory mitigation success will be determined once all metric targets with a Year number and consecutive period have been achieved. If an adaptive management action is implemented with the intent to achieve a target value, not to maintain or adjust it, the monitoring time-period will reset but will not exceed 10 years from the initial monitoring activities.

## X. Long-term Management Plan

Long-term management of the mitigation site will be ensured in perpetuity under a legal Conservation Easement and through land ownership by the DNER. The DNER will be responsible for management and maintenance activities, once the Corps has determined that the compensatory mitigation was successful or after 10 years of monitoring, whichever occurs earlier.

## XI. Contingency Adaptive Management

Contingency adaptive management will be employed to address unforeseen challenges and optimize project performance. Shorter time intervals during the initial years of monitoring are intended to identify any necessary corrective action/s.

Potential adaptive management actions include:

| **Problem** | **Potential Adaptive Management Action** |
|---|---|
| Low mangrove survival rates | Reassess species-sites matching conditions, supplemental planting during favorable conditions, improve site preparation, reduce herbivore pressure, remove biofoul from roots and/or trunks |
| Low growth rates | Reassess species-sites matching conditions, improve hydrological conditions, fertilize organically if nutrient-limited |
| Low natural recruitment | Manually assisted recruitment, install seed traps or propagule retainers, reduce herbivore pressure |
| Disease, pests, and invasive and nuisance species | Targeted removal efforts, source disease-free plants/seedlings, use plant protectors, biological and/or chemical controls (if appropriate) |
| Hydrological alterations | Reassess elevations, adjustments to hydrological features, restoration of natural drainage |

## XII. Financial Assurances

Standard Corps QA/QC contracting mechanisms will be in place as the contract will be part of the overall Río Puerto Nuevo Flood Control Project.

## XIII. Compensatory Mitigation Plan Compliance

This Wetland Mitigation and Contingency Plan for the RPN Project SEA Preferred Alternative has been prepared in accordance with, and is compliant with, all applicable federal, state, and local laws, regulations, and executive orders. Specifically, this plan addresses requirements under Section 404 of the Clean Water Act, and USACE regulations (33 CFR Parts 320-330) regarding compensatory mitigation for unavoidable wetland impacts. The plan also adheres to guidance outlined in the Compensatory Mitigation for Losses of Aquatic Resources (33 CFR Part 332 and 40 CFR Part 230). Lastly, this plan supports compliance with Executive Order 11990 (Wetland Protection) by demonstrating a commitment to avoiding and minimizing wetland impacts, and by providing for the restoration and enhancement of wetland resources to achieve no net loss of wetland function and value.

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# Appendix A

## Habitat Unit and Average Annual Habitat Unit Calculations

Excerpt from the USFWS Habitat Evaluation Procedures (102 ESM)

# Habitat Evaluation Procedures (HEP)

## ESM 102

Division of Ecological Services
U.S. Fish and Wildlife Service
Department of the Interior
Washington, D.C.

## 4. Calculating Study Area Habitat Units

A HEP analysis is structured around the calculation of Habitat Units (HU's) for each evaluation species in the study area. The number of HU's is defined as the product of the Habitat Suitability Index (quality) and the total area of available habitat (quantity). This chapter provides some basic guidelines for determining HSI and total available habitat area for evaluation species. Chapter 5 discusses the use of HU's in habitat assessments for both baseline and impact studies.

4.1 Calculating total area of available habitat. The total area of available habitat for an evaluation species includes all areas that can be expected to provide some support to the evaluation species. Total area of available habitat is calculated by summing the areas of all cover types likely to be used by the evaluation species. If the study area is not subdivided into cover types, the total area of available habitat is identical to the entire study area.

The objective of defining total area of available habitat is to delineate only those areas that require HSI determinations. The total area of available habitat will vary between evaluation species if cover type use patterns are different; therefore, HSI's for each evaluation species may apply to different subareas (i.e., available habitat).

4.2 Calculating a Habitat Suitability Index for available habitat. The fundamental step in determining HU's is to estimate or calculate HSI's for each evaluation species. The technique for determining HSI values must be clearly described in a HEP study in order to establish credibility, optimize the usefulness of the analysis in decisionmaking, provide a permanent record of the basis for a decision, and make future improvements in HSI models. Studies by Ellis et al. (1979) confirmed that such descriptions increase the repeatability in determining HSI values. Although repeatability does not mean that HSI values will be accurate, repeatability is a prerequisite to improved accuracy.

The recommended method of describing HSI values is through the use of HSI models. An HSI model may be in word or mathematical format but, regardless of the format, the model must clearly describe the rules and assumptions used to calculate an HSI. The process of calculating an HSI involves: 1) establishing HSI model requirements; 2) acquiring an HSI model; and 3) determining HSI for available habitat.

A. Establishing HSI model requirements. Habitat models used in HEP must be in index form. Inhaber (1976) defined an index as a ratio between some value of interest and a standard of comparison. For HEP purposes, the value of interest is an estimate of habitat conditions in the study area, and the standard of comparison is the optimum habitat condition for the same evaluation species. Therefore,

$$\text{Index value} = \frac{\text{Value of Interest}}{\text{Standard of Comparison}} \text{ ; or}$$

$$HSI = \frac{\text{Study Area Habitat Conditions}}{\text{Optimum Habitat Conditions}}$$

where the numerator and denominator have the same units of measure. The HSI ranges between 0 and 1.0 and, as with any index, is dimensionless (i.e., the units for both the numerator and denominator must be the same and should be specified).

The ideal goal of an HSI model is to produce an index with a proven, quantified, positive relationship to carrying capacity (i.e., units of biomass/unit area or units of biomass production/unit area). This ideal model goal will often be unobtainable; consequently, a more easily obtainable but acceptable goal must be defined. The minimum acceptable goal for an HSI model might be, for example, an index that a recognized expert, knowledgeable about the habitat requirements of a species, believes is positively related to long-term carrying capacity.

The use of an HSI model within HEP places additional requirements on HSI values. The HEP mechanisms for comparing proposed actions and developing compensation plans are based on the assumption that HSI is a linear index; i.e., a change in HSI from 0.1-0.2 is the same magnitude as a change from 0.8-0.9. Even if the HSI model used has a proven, positive relationship to long-term carrying capacity, the relationship must be linear (or transformable to linear). It is not necessary to obtain a model that meets the ideal goal if assumptions concerning the linear relationships of the index to carrying capacity are acceptable.

B. Acquiring HSI models. In acquiring an HSI model for use in HEP, the ideal goal, as stated previously, is to use a model that has been proven to be linearly correlated with a defined measure of carrying capacity (e.g., biomass/unit area or biomass production/unit area). There are two basic categories of models that may be used with HEP: 1) HSI models that directly produce a unitless number between 0 and 1 that is believed (or assumed) to have a positive relationship with carrying capacity; or 2) HSI models with a predictable value of interest (i.e., the numerator is estimated in some specified units, such as lbs per acre).

(1) Existing habitat models. HSI models are under development by the USFWS[2] and several reservoir models are now available in Aggus and Morais (1979). Models have been described that can be converted

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[2] Contact USFWS, Western Energy and Land Use Team, 2625 Redwing Road, Fort Collins, Colorado 80526.

to HSI format. The Aquatic Systems and Instream Flow Group has developed a method of assessing change in fish habitat potential in streams in response to change in stream flow or channel configuration (Bovee 1978; Stalnaker 1978; Stalnaker 1980). This method involves modeling habitat within selected stream reaches. Training and technical assistance in the use of this method is available from the Aquatic Systems and Instream Flow Group. Terrestrial habitat models that predict population densities based on statistical methods have been developed by Russell *et al*. (1980).[3] These models use conditional probability statements derived through habitat observations in areas of both high and low population densities.

Tested and scaled regression models relating habitat variables to population measures are available for reservoir fishes (Jenkins 1976; Leidy and Jenkins 1977; Aggus and Morais 1979) and some stream fishes (Binns and Eiserman 1979) and should be reviewed for potential HEP applications. In addition, certain species data bases are being developed by the U.S. Forest Service and other agencies and may be useful in HSI modeling.

If there are existing models, judgment may be required in adapting them for specific applications. Almost all models are developed around a specific set of assumptions that may or may not apply to a specific application area. An existing habitat model may be constructed around habitat variables (e.g., % canopy cover or tree height) that do not relate to habitat suitability in all regions of the country where the species occur.

The use of existing habitat models in HEP requires that model outputs be in a 0 to 1 index form. Models that output a measure of habitat suitability that are not a 0 to 1 index should be converted to an HSI as follows:

$$\text{HSI} = \frac{\text{Model Output (Study Area Habitat Conditions)}}{\text{Optimal Habitat Conditions}}$$

For example, the output of the model developed by the Aquatic Systems and Instream Flow Group is weighted useable area (WUA) for appropriate instream habitat types (spawning, fry, juvenile, adult). This information is displayed for selected stream reaches at monthly intervals (Stalnaker 1980). Suitability indices for each habitat type may be calculated as follows:

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[3] The use of these models may require assistance from the Colorado Cooperative Wildlife Research Unit, Colorado State University, Fort Collins, Colorado.

$$SI_i = \frac{\text{Weighted Useable Area (WUA) of the Stream Reach Modeled}}{\text{Wetted Surface Area of the Same Stream Reach}}$$

where $i$ = instream habitat type

$SI_i$ = suitability index for a given stratified stream segment described by the representative reach samples.

These SI values must be aggregated into an HSI value. The physical habitat simulation model (PHABSIM) developed by the Aquatic Systems and Instream Flow Group can be used to predict WUA changes in stream environments under proposed alterations of streamflow or channel geometry. This model output can then be used to calculate future HSI values. The Instream Flow Group is currently preparing a detailed illustration of the application of the IFG Incremental Methodology in a HEP analysis.

The output of the model described by Russell et al. (1980) is a population density estimate. This estimate can be converted to an HSI as follows:

$$HSI = \frac{\text{Population Density Estimates (Model Output)}}{\text{Maximum Observed Population Density}}$$

(2) Development of HSI models. If an HSI model must be developed, 103 ESM should be consulted for full details of the model building process. The following discussion is a summary of the modeling process and is meant to be an aid to understanding how an HSI model may be constructed.

The general steps in the construction of a model are: 1) establish a model goal; 2) define the habitat variables that are related to the model goal; and, 3) define model relationships that combine measurements of the variables to achieve model goals.

Model goals include two general aspects: 1) output specifications and 2) a definition of potential variables the field biologist is able to measure. The ideal output for an HSI model is a measure of habitat suitability per unit area (e.g., biomass or biomass production/unit area). In order to provide a rapidly applicable assessment tool, habitat models for use in HEP should be based on easily measured physical, chemical, or vegetative variables. After reviewing the literature about the evaluation species, the proper variables to measure can usually be identified. States et al.

(1978) described variables commonly measured in aquatic and terrestrial systems, noted why variables were important, and discussed references on how to measure them.

The relationship between model variables can be defined in word or mathematical format. In word format, a definition of optimum habitat is developed through a written description of the best condition of habitat variables. A description of the habitat in the study area, based on the same variables, is developed and compared to the word model to determine the HSI. The data and logic used to determine the HSI must be described.

A mathematical format is a more rigorous approach and requires that the logic of the HSI calculation be mathematically defined. HSI values are determined by mathematical functions that combine habitat variable measurements. A mathematical format allows clearer statements of model relationships but is not necessarily any less subjective than a model in word format. The mathematical functions need not be complex, but should consider the biological interactions of variables.

Ideally, an HSI model should be calibrated to the desired output goal. Significant assumptions are required concerning the attainment of model output goals (e.g., number of animals/hectare) until the model has been tested and scaled by comparing it to a defined measure of habitat suitability.

C. Determining HSI for available habitat. After a habitat model is obtained, the model must be used in HEP to obtain an HSI for the available habitat. The HSI for available habitat is a function of the suitability of all cover types used by the evaluation species. The HSI for available habitat is calculated in one of several ways; the choice depends on the structure of the model. Figure 4-1 displays the various routes to calculating an HSI for available habitat. These routes are dependent on the structure of the model and can be defined by answering three questions about the model structure: 1) Does use of the model produce suitability indices (SI's) for the available habitat from individual cover type suitability indices?; 2) If cover type suitability indices are calculated, does the available habitat for the species consist of more than one cover type?; and 3) If the available habitat consists of more than one cover type, is interspersion between cover types important for the species?

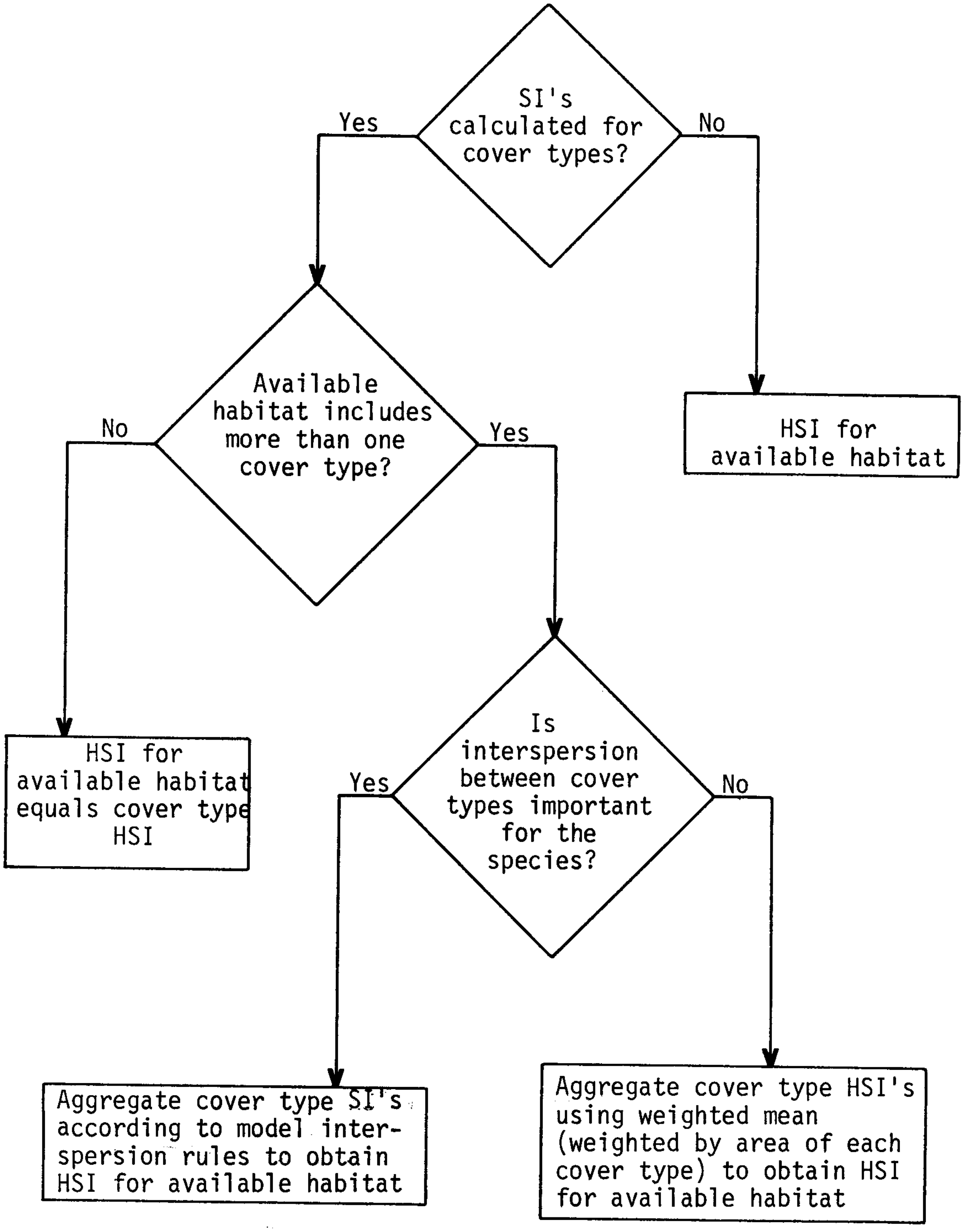


Figure 4-1. Options for calculating HSI for available habitat.

## 4. Calculating Study Area Habitat Units

In response to the first question in Figure 4-1, if the habitat model does not produce cover type suitability indices then all pertinent habitat variables, including interspersion, will be combined in one relationship. Examples of models of this type are provided by Russell et al. (1980). Different calculations are necessary if cover type suitability indices are produced by the model. Models that provide suitability indices for evaluation species by cover type are being developed by the Habitat Evaluation Procedures Group (USFWS, Fort Collins, Colorado) and are described in more detail in 103 ESM.

Each cover type within the available habitat is assigned a suitability index for only those resources provided by the cover type (e.g., food, reproductive cover). The indices applied to individual cover types are not necessarily habitat suitability indices because they may only apply to part of the species' habitat needs.

A second question is necessary if the model produces cover type indices: Does the available habitat for a species include only one cover type? If all habitat needs are met by one cover type, then the HSI for available habitat is equivalent to the cover type suitability index. If the available habitat consists of two or more cover types, then methods are required to aggregate cover type indices into an HSI for available habitat. The aggregation methods are defined by the third question in Figure 4-1. If interspersion between cover types is important, then the model should aggregate cover type HSI's into one HSI value. For example, optimum habitat conditions for species A might be a 2:1 ratio of cover type A (that provides suitable food) to cover type B (that provides suitable cover), with the added requirement that only those portions of the cover types which are within 300 m of each other should be considered as optimum habitat. If a species occurs in more than one cover type, but interspersion between cover types is not important (i.e., all habitat needs are provided by each cover type), then a different aggregation method is required. This latter aggregation method is a simple weighted mean of the suitability indices for the cover types (weighted by the area of each cover type).

All models have specific data requirements that influence data collection tasks. If a model is structured to compute cover type suitability indices, then data must be collected for each cover type. Baseline habitat conditions typically will be based on field data collection at several selected sites within each cover type. HSI's for future years typically will be based on a predicted average value of the habitat variables within each cover type, without the use of field sample sites. Spatial variables (interspersion of cover types) are best computed from maps. The same basic data collection options can also be used for other model types by sampling in the field to compute mean values of variables or estimating areawide average values of variables.

## 5. Habitat Assessments Using Habitat Units

Habitat assessments involve measurement and description of habitat conditions for baseline (present) assessments and impact (future with and without action) assessments. For baseline assessments, different areas can be compared in terms of HU's as a guide to further land use planning. Baseline assessments are point-in-time comparisons. For impact assessments, alternative future land use actions can be compared based on predicted future availability of HU's. The net impact of a proposed land use action is the difference in predicted HU's between the future with the action and the future without the action.

5.1 Habitat Unit analysis for one point in time - Baseline assessments. Baseline assessments are used to describe existing ecological conditions. The results of baseline assessments provide a reference point from which resource planners can: 1) compare existing conditions in two or more areas in order to define management capabilities or as a guide to future land use planning; 2) predict and compare changes that may occur without the proposed action, with the proposed action, or with compensation measures; and 3) design monitoring studies. Baseline assessments play a critical role in wildlife planning by identifying wildlife resource capabilities at one point in time so that proposed future actions can be directed toward or away from specific areas. A baseline assessment involves: 1) definition of the study limits, including definition of the study area, delineation of cover types, and selection of evaluation species (Chapter 3); and 2) characterization of the study area in terms of HU's (Chapter 4).

The objective in performing a baseline assessment is to calculate the number of HU's at one point in time for each evaluation species. The area of available habitat (Section 4.1) is multiplied by the mean HSI (Section 4.2) for each evaluation species to determine the total HU's for that species in the study area. The baseline HU's are evaluated and compared directly if the baseline assessment is designed to compare existing conditions in two or more areas. Additional calculations are required (Section 5.2) if the baseline data are to be used as a reference point for impact assessments.

5.2 Habitat Unit analysis for multiple points in time - Impact assessments. Impact assessments are performed by quantifying habitat conditions at several points in time throughout some defined period of analysis. Points in time (target years) can be selected at fixed intervals such as every year, or according to some other schedule.

The assessment of land use impacts is facilitated by dividing the study area into impact segments. An impact segment is defined as an area in which the nature and intensity of the future land use can be considered homogeneous, such as the flood pool area in a reservoir project, a recreational area, or the area of a particular agricultural practice. The advantage of dividing the study area into impact segments is that only one condition need be considered for each cover type within each impact segment. The effects of a particular action may be analyzed over a large area by assuming that the same condition exists throughout each impact-segment-cover-type zone.

Habitat Units must be calculated for the evaluation species at each of the future points in time for future-with and future-without project conditions; this process includes predicting total available habitat and HSI for each evaluation species, using the same HSI models that were used for the baseline year.

A. Use of target years for future predictions. The impact assessment can be simplified by selecting target years (TY's) for which habitat conditions can be reasonably defined. At a minimum, target years should be selected for points in time when the rates of loss or gain in HSI or area are predicted to change. Rates of loss or gain in HSI or area are assumed to occur linearly between target years.

   There are several requirements for the selection of target years. The HU-time analysis must begin at a baseline year (TY-0). A baseline year is defined as a point in time before proposed changes in land and water use result in habitat alterations in the study area. In most cases, the baseline year will be existing or current year conditions. However, in some cases, current habitat conditions may reflect proposed action influences. For example, landowners or managers may begin clearing bottomland timber from flood prone sites located downstream from an anticipated flood control project before baseline studies can be initiated. In such cases, baseline year conditions will be those that existed in some previous year. Judgment is required in defining baseline year habitat conditions when present conditions reflect proposed action influences.

   In addition to a baseline year, there must always be a target year 1 and an ending target year which defines the future period of analysis. Target year 1 is the first year land and water use conditions are expected to deviate from baseline conditions. The habitat conditions (HSI and area) described for each target year are the expected conditions at the end of that year.

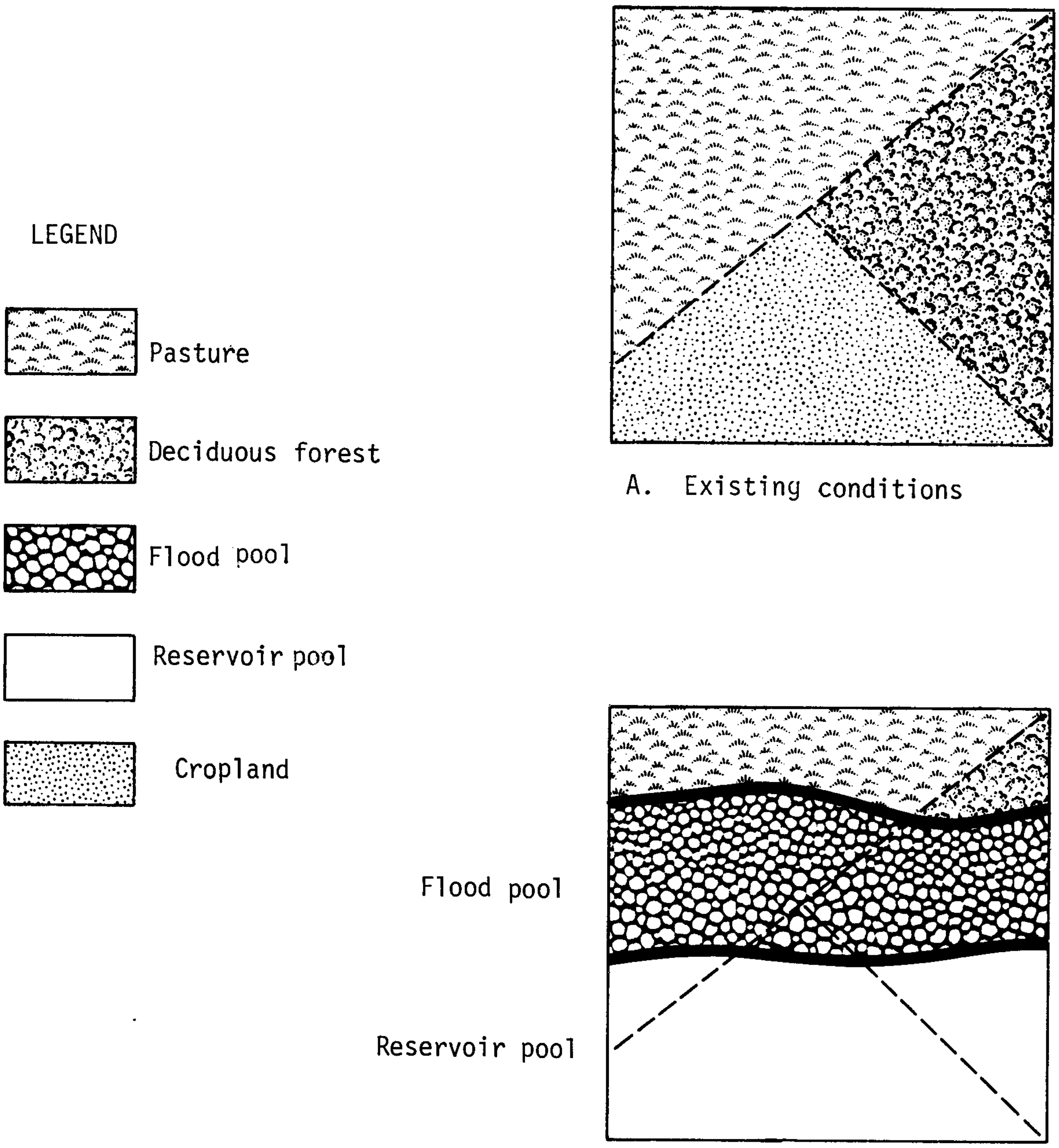
B. Predicting future area of available habitat. For each proposed action, the area of available habitat must be estimated for future years. Some cover types will increase in total area, others will decrease, and in some cases new cover types will be created or existing ones totally lost under projected future conditions.

The user must constantly check to ascertain that the total area of the study does not vary from the baseline area. The recommended method for determining the future area of cover types is the use of cover type maps. The method of developing a cover type map for a future year is to overlay impact segment boundaries on the baseline cover map previously developed (Section 3.2). Baseline cover types will either be unaltered, altered (i.e., variables such as % vegetation cover may change), or converted to new cover types depending on such factors as land use within the impact segment, vegetation successional trends, and management. Areas converted to new cover types through succession or impacts are given a new cover type designation. Altered cover types are designated a subtype (e.g., deciduous forest altered by flooding). An overlay of impact segment boundaries may be required for each target year. Each proposed action requires its own series of overlays in order to determine changes in area of available habitat between selected target years. Figure 5-1 illustrates how a baseline cover type map could be used in conjunction with impact segments to produce cover type maps for future conditions.

C. Predicting future HSI. The same models that were used to determine baseline HSI values must be used to determine future HSI values. If, for example, a mathematical model was used to calculate baseline HSI, a related word model cannot be used to predict future HSI values, or vice versa.

Estimating HSI values for future years requires predictions of changes in the physical, vegetative, and chemical variables of each cover type. Impact segment overlays can be used as an aid in estimating these variables. For example, seasonal flooding could alter a forest understory but not the canopy closure. Changes in interspersion relationships due to creation of new cover types or conversion of existing cover types also can affect HSI model output and can be easily measured on future cover type maps (impact segment overlays).

D. Annualization of impacts. Most Federal agencies use annualization as a means to display benefits and costs, and the habitat analysis should provide data that can be directly compared to the benefit/cost analysis. The annualization process will be described in detail, although it is not the only mechanism with which to display future habitat changes. Federal projects are evaluated over a period of time that is referred to as the "life of the project" and is defined as that period between the time that the project becomes operational and the end of the project life as determined by the construction, or lead, agency. However, in many cases gains or losses in wildlife habitat may occur before the project becomes operational, and these changes should be considered in



A. Existing conditions

B. Proposed action conditions

Figure 5-1. An example of a cover type map illustrating existing habitat conditions (A) and predicted conditions for target year 20 with a proposed action (B).

the impact analysis. Examples of such changes include construction impacts, implementation of a compensation plan, or other land use changes. The habitat assessment incorporates these changes by use of a period of analysis that includes prestart impacts (Figure 5-2). However, if no prestart changes are evident, then the life of the project and the period of analysis are the same.

Habitat Unit gains or losses are annualized by summing HU's across all years in the period of analysis and dividing the total (cumulative HU) by the number of years in the life of the project. In this manner prestart changes can be considered in the analysis. This calculation results in Average Annual Habitat Units (AAHU's).

The area of the shaded portion of the graph in Figure 5-3 represents the cumulative HU's for all years in the period of analysis and is calculated by summing the products of HSI and area of available habitat for all years in the period of analysis as follows:

$$\text{Cumulative HU's} = \sum_{i=1}^{p} H_i \, (A_i) \qquad (1)$$

where $H_i$ = HSI at year i

$A_i$ = area of available habitat at year i

$p$ = the period of analysis (e.g., 100 years)

This is a generalized formula and requires that the HSI and area of available habitat be known for each year. However, a formula that requires only target year HSI and area estimates is:

$$\text{Cumulative HU's} = (T_2 - T_1)\left[\frac{A_1H_1 + A_2H_2}{3} + \frac{A_2H_1 + A_1H_2}{6}\right] \qquad (2)$$

where $T_1$ = first target year of time interval

$T_2$ = last target year of time interval

$A_1$ = area of available habitat at beginning of time interval

$A_2$ = area of available habitat at end of time interval

$H_1$ = HSI at beginning of time interval

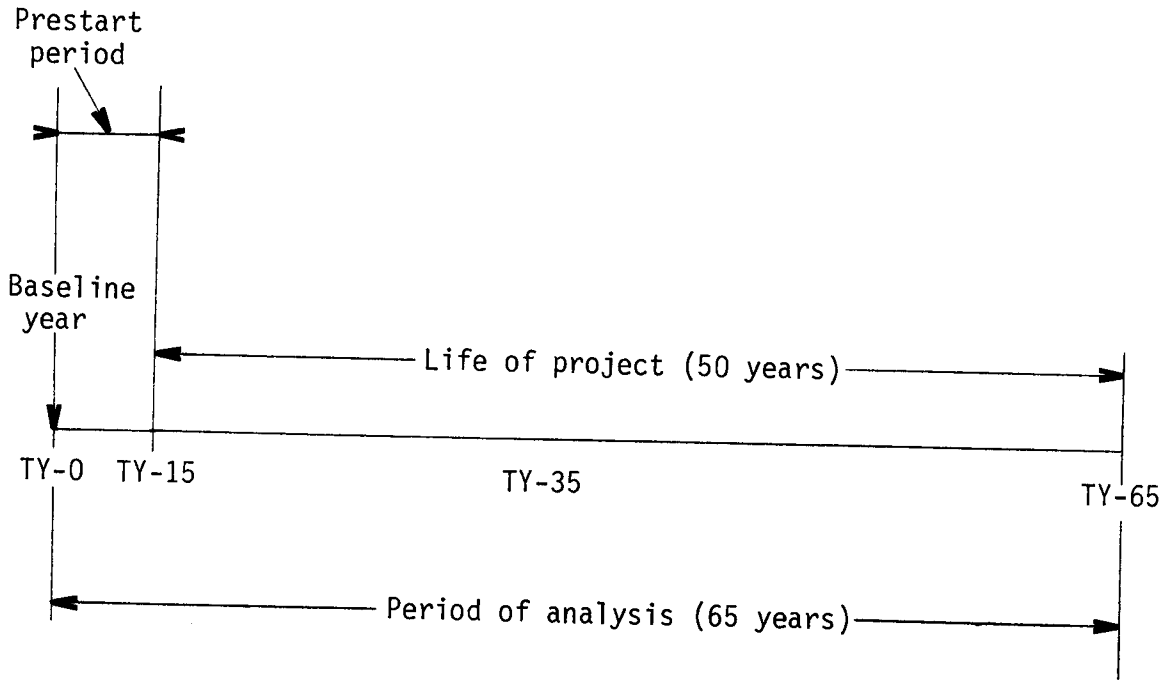


Figure 5-2. Relationship between the "life of the project" and the "period of analysis".

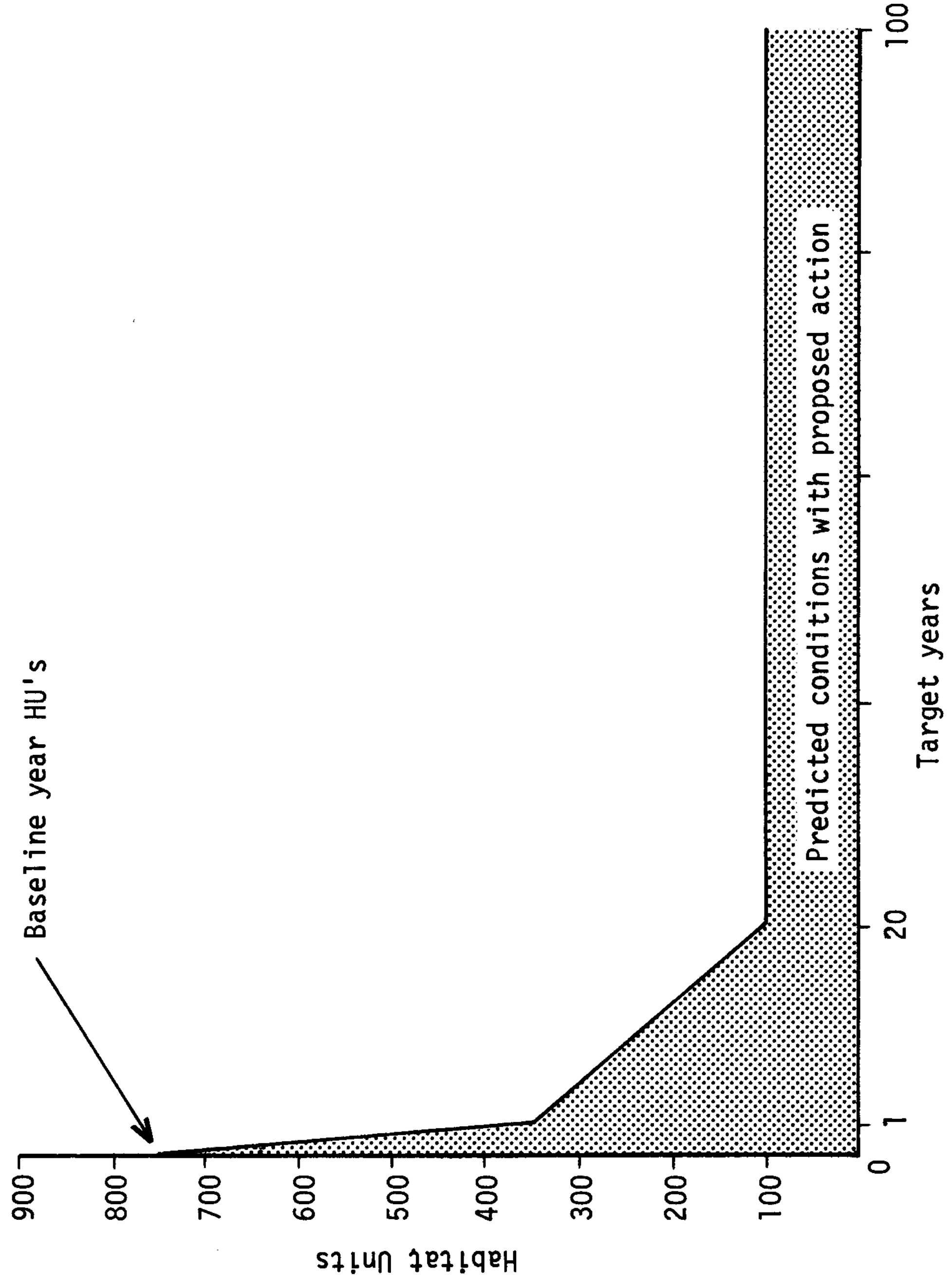


Figure 5-3. Change in white-tailed deer HU's for a hypothetical reservoir project. Shaded area represents the cumulative habitat availability with the proposed action.

$H_2$ = HSI at end of time interval

3 and 6 = constants derived from integration of HSI x Area for the interval between any two target years

Formula (2) is applied to the time intervals between target years. For the example in Figure 5-3, the formula must be applied for three time intervals: baseline to year 1, year 1 to year 20, and year 20 to year 100. The formula was developed to precisely calculate cumulative HU's when either HSI or area or both change over a time interval. The rate of change of HU's may be linear (either HSI or area is constant over the time interval), or curvilinear (both HSI and area change over the time interval); the formula will work in either case.

E. Calculating net impacts of a proposed action. The preceding example illustrates the calculation of AAHU's for one set of future conditions. However, determining the net impact of a proposed action requires that two future analyses be performed and compared to one another: 1) expected future conditions with the proposed action; and 2) the future without the proposed action. When comparing future conditions, the same baseline year and period of analysis must be used for each. Table 5-1 presents a hypothetical set of data for white-tailed deer habitat for the future with and the future without a proposed action.

Table 5-1. Target year habitat conditions for white-tailed deer for both the future with and the future without a proposed action.

| Condition | Target year | Area (acres) | HSI value | Total HU |
|---|---|---|---|---|
| With proposed action | Baseline | 1000 | 0.75 | 750 |
| | 1 | 500 | 0.70 | 350 |
| | 20 | 500 | 0.20 | 100 |
| | 100 | 500 | 0.20 | 100 |
| Without proposed action | Baseline | 1000 | 0.75 | 750 |
| | 1 | 1000 | 0.75 | 750 |
| | 20 | 900 | 0.60 | 540 |
| | 100 | 600 | 0.60 | 360 |

Using formula (2) for cumulative HU's, the AAHU calculations for the future with the proposed action are as follows:

Baseline - 1

$$\text{A.}\quad (1-0)\left[\frac{1000(0.75)+500(0.70)}{3}+\frac{500(0.75)+1000(0.70)}{6}\right]=545.8$$

Years 1-20

$$\text{B.}\quad (20-1)\left[\frac{500(0.70)+500(0.20)}{3}+\frac{500(0.70)+500(0.20)}{6}\right]=4275$$

Years 20-100

$$\text{C.}\quad (100-20)\left[\frac{500(0.20)+500(0.20)}{3}+\frac{500(0.20)+500(0.20)}{6}\right]=8000$$

Cumulative HU's = 545.8 + 4275 + 8000 = 12820.8

$$\text{AAHU's} = \frac{12820.8}{100} = 128.2$$

The AAHU calculations for the future without the proposed action are as follows:

Baseline - 1

$$\text{A.}\quad (1-0)\left[\frac{1000(0.75)+1000(0.75)}{3}+\frac{1000(0.75)+1000(0.75)}{6}\right]=750$$

Years 1-20

$$\text{B.}\quad (20-1)\left[\frac{1000(0.75)+900(0.60)}{3}+\frac{900(0.75)+1000(0.60)}{6}\right]=12{,}208$$

Years 20-100

$$\text{C.}\quad (100-20)\left[\frac{900(0.60)+600(0.60)}{3}+\frac{600(0.60)+900(0.60)}{6}\right]=36{,}000$$

Cumulative HU's = 750 + 12,208 + 36,000 = 48,958

$$\text{AAHU's} = \frac{48{,}958}{100} = 489.6$$

The net annual impact of the proposed action on white-tailed deer is calculated by using the formula:

$$\text{NET IMPACT} = \text{AAHU}_{\text{WITH}} - \text{AAHU}_{\text{WITHOUT}}$$

$$= 128.2 - 489.6$$

$$= -361.4 \text{ AAHU}$$

The net impact figure reflects in AAHU's the difference between future with and future without the proposed action conditions. An average of 361.4 fewer HU's will be available for deer every year during the life of the proposed action than would be available if the proposed action was not implemented. Figure 5-4 illustrates this relationship.

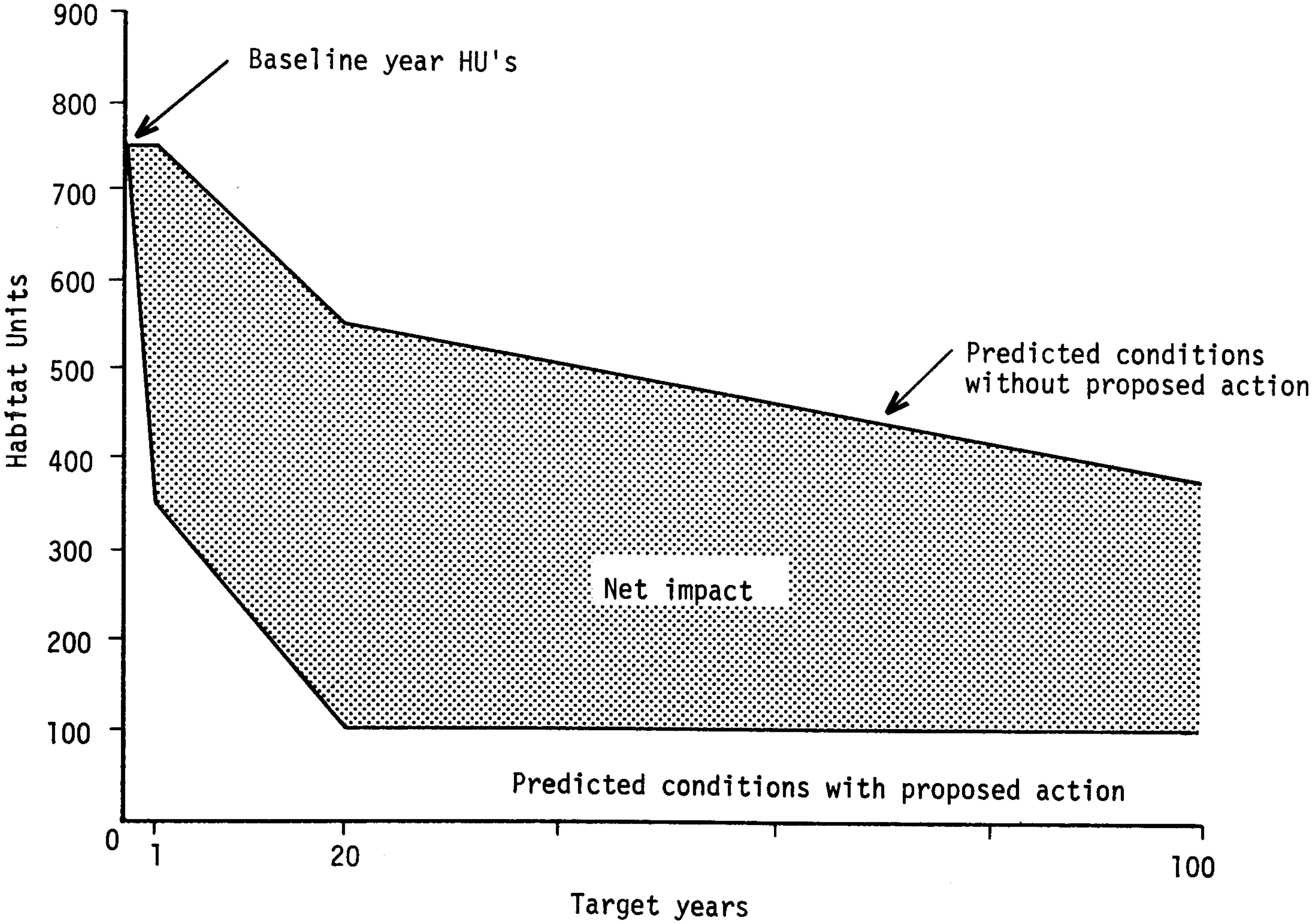


Figure 5-4. Relationship between baseline, conditions without a proposed action, conditions with a proposed action, and net impact.