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# SECTOR ENVIRONMENTAL GUIDELINE:

# ROADS

## Full Technical Update, 2023

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# SECTOR ENVIRONMENTAL GUIDELINE: ROADS

## Full Technical Update

## September 2023

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# ABOUT THIS DOCUMENT AND THE SECTOR ENVIRONMENTAL GUIDELINES

USAID has developed sector-specific environmental and social guidance to support activity design, pre-implementation environmental review (including the identification of potential impacts and the design of mitigation and monitoring measures), and the development of environmental mitigation and monitoring plans. **This document presents USAID's *Sector Environmental Guideline – Roads***. The *Sector Environmental Guidelines* for all sectors are available at [https://www.usaid.gov/environmental-procedures/sectoral-environmental-social-best-practices/sector-environmental-guidelines-resources](https://www.usaid.gov/environmental-procedures/sectoral-environmental-social-best-practices/sector-environmental-guidelines-resources).

**Purpose.** The purpose of this document and the *Sector Environmental Guidelines* overall is to support environmentally sound design and management of common USAID sectoral development activities by providing concise, plain language information regarding:

- The typical potential adverse impacts of activities in these sectors;
- How to prevent or otherwise mitigate these impacts, both in the form of general activity design guidance and specific design, construction, maintenance, and operating measures;
- How to minimize the vulnerability of activities to climate change; and
- More detailed resources for further exploration of these issues and possible solutions.

**Environmental Procedures.** USAID's mandatory life-of-project environmental procedures require that an environmental analysis be conducted to identify the potential adverse impacts of USAID-funded and -managed activities prior to their implementation. They also require that the environmental management or mitigation measures ("conditions") identified by this analysis be written into award documents, implemented over the life of project, and monitored for compliance and sufficiency. USAID's mandatory environmental requirements are detailed in the Code of Federal Regulations under 22 CFR 216 Environmental Procedures (Reg 216) (22CFR216 2023) and in the Automated Directives System (ADS) (USAID 2023a), primarily ADS 204 Environmental Procedures and ADS 201 Program Cycle Operational Policy and its mandatory references on climate change (ADS 201mal and ADS 201mat) and construction risk (ADS 201maw).

The procedures are USAID's principal mechanism to help ensure environmentally sound design and management of USAID-funded activities and thus protect environmental resources, ecosystems, and the health and livelihoods of beneficiaries and other groups. They strengthen development outcomes and help safeguard the good name and reputation of USAID.

The *Sector Environmental Guidelines* directly support environmental compliance by providing information essential to the assessment of potential impacts of activities and the identification and detailed design of appropriate mitigation and monitoring measures. When an activity receives a "Negative Determination with Conditions," these guidelines should be used to help establish which conditions are appropriate for the particular activity.

However, the *Sector Environmental Guidelines* are not specific to USAID's environmental procedures. They are generally written and are intended to support environmentally and socially sustainable approaches to common sectors, regardless of the specific environmental requirements, regulations, or processes that may apply. Site-specific context must be considered when using these guidelines and additional or modified impacts and mitigation measures may be required.

**Limitations.** This document serves as an introductory tool for Agency staff and Implementing Partners dealing with road sector projects, programs, and activities. This document is not intended to act as a complete compendium of all significant environmental impacts because contextual information is critical in determining those impacts. Furthermore, *Sector Environmental Guidelines* are not a substitute for detailed sources of technical information or design manuals. Users are expected to refer to the accompanying list of references and resources for additional information, as well as other resources not included in this document.

**USAID Guidelines Superseded.** This *Sector Environmental Guideline – Roads* (2023) replaces *Sector Environmental Guidelines – Rural Roads* (2018).

**Comments and Corrections.** Each sector of these guidelines is a work in progress. Comments, corrections, and suggested additions are welcome. Email: environmentalcompliancesupport@usaid.gov.

**Advisory.** The *Sector Environmental Guidelines* are advisory only. They are not official USAID regulatory guidance or policy. Following the practices and approaches outlined in the *Sector Environmental Guidelines* does not necessarily ensure compliance with USAID Environmental Procedures or host country environmental requirements.

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# LIST OF ACRONYMS

| | |
|---|---|
| ADS | Automated Directives System |
| AOR | Agreement Officer's Representatives |
| BEO | Bureau Environmental Officer |
| CDR | Compulsory Displacement and Resettlement |
| CFR | Code of Federal Regulations |
| CO | Carbon Monoxide |
| COR | Contracting Officer's Representative |
| EA | Environmental Assessment |
| EIS | Environmental Impact Statement |
| EMMP | Environmental Mitigation and Monitoring Plan |
| ERC | Environmental Review Checklist |
| ERF | Environmental Review Form |
| ESIA | Environmental and Social Impact Assessment |
| ESV | Ecosystem Service Valuation |
| GIS | Geographic Information System |
| GPS | Global Positioning System |
| GRM | Grievance Redress Mechanism |
| HSP | Health and Safety Plan |
| HIV/AIDS | Human Immunodeficiency Virus/Acquired Immunodeficiency Syndrome |
| IEE | Initial Environmental Examination |
| IFC | International Finance Corporation |
| IP | Implementing Partner |
| MEO | Mission Environmental Officer |
| NEPA | National Environmental Policy Act |
| NOx | Nitrogen Oxides |
| O&M | Operations and Maintenance |
| PAH | Polycyclic Aromatic Hydrocarbon |
| PERSUAP | Pesticide Evaluation Report and Safer Use Action Plan |
| PM10 | Particulate matter less than 10 micrometers in diameter |
| PM2.5 | Particulate matter less than 2.5 micrometers in diameter |
| PPE | Personal Protective Equipment |
| RCE | Request for Categorical Exclusion |
| REA | Regional Environmental Adviser |
| SEG | Sector Environmental Guideline |
| $SO_2$ | Sulfur Dioxide |
| STD | Sexually Transmitted Disease |
| SWPP | Stormwater Pollution Prevention Plan |
| USAID | United States Agency for International Development |
| VOC | Volatile Organic Compound |

# 1 INTRODUCTION

USAID has developed sector-specific environmental and social guidance to support activity design, pre-implementation environmental review (including the identification of potential impacts and the design of mitigation and monitoring measures), and the development of environmental mitigation and monitoring plans. **This document presents USAID's *Sector Environmental Guideline – Roads***. The *Sector Environmental Guidelines* for all sectors are available at https://www.usaid.gov/environmental-procedures/sectoral-environmental-social-best-practices/sector-environmental-guidelines-resources.

## 1.1 THE ORGANIZATION OF THIS GUIDELINE

Section 2, Overview of USAID Activities in the Roads Sector, discusses the types of road projects in which USAID may be involved and presents the overall scope of managing their environmental and social impacts.

Section 3, Road Construction and Operation, describes road construction and operation. This section describes the construction activities to facilitate a common understanding of the activities that may have environmental and social impacts. The potential impacts and mitigation measures from those activities are discussed in Sections 4 and 5.

Section 4, Environmental and Social Impacts and Mitigation Measures – Road Construction, describes the potential environmental impacts from the construction activities discussed in Section 3. The discussion of mitigation measures immediately follows the impact descriptions so that the reader can clearly understand the relationship between them.

Section 5, Environmental and Social Impacts and Mitigation Measures – Road Operation, describes the potential environmental impacts from the post-construction existence and operation of the road.

## 1.2 THE PURPOSE OF THIS GUIDELINE

The primary intended audience for this Sector Environmental Guideline (SEG) is USAID Project Design Teams, Agreement Officer's Representatives/Contracting Officer's Representatives (AORs/CORs) and Implementing Partners (IPs). The secondary intended audience consists of other USAID staff with design, monitoring and evaluation, and environmental compliance responsibilities and other actors involved in the design, implementation, and monitoring of development activities in the road sector. Brief recommendations on the use of the guidelines for these user groups are provided below.

**AGENCY TECHNICAL OR PROGRAM OFFICE STAFF** who are designing or providing technical expertise to colleagues and missions on road projects and activities may find Sections 2, 4, and 5 most useful. These sections establish the framework for road project environmental compliance for USAID actions and discuss typical potential negative environmental impacts and mitigation measures.

**PROJECT DESIGN TEAMS, AORS/CORS, AND ACTIVITY MANAGERS** must work together with their IPs to address potential environmental and social impacts throughout the project life cycle, from project planning through construction and operation. They can use all sections of this SEG to help guide them through these processes and to ensure that road projects are developed and implemented to avoid or minimize adverse environmental and social impacts.

**IN-COUNTRY AND REGIONAL MISSION STAFF**, such as in-country Activity Managers, Mission Environmental Officers (MEOs), and Environmental Compliance Officers, will find Sections 2 and 3 to be useful for project and activity design, including key elements to address in Initial Environmental Examinations (IEEs). Sections 4 and 5 will be most useful for oversight of IPs in planning, monitoring, and reporting on environmental mitigation measures during project implementation.

**IPs** will benefit from the project and activity guidance provided throughout the SEG, especially the descriptions of road construction activities in Section 3 and the impacts and mitigation measures in Sections 4 and 5. This guidance may be useful at various stages, including the development of work plans, activity planning, and/or the development of Environmental Mitigation and Monitoring Plans (EMMPs).

The References and Resources section also may be useful for this group of users as they search for more in-depth guidance on specific issues or locations.

## 1.3 NOTES FOR DEVELOPERS OF ENVIRONMENTAL DOCUMENTS

This SEG is intended to describe the basic elements of road projects to assist with the evaluation and mitigation of potential environmental impacts, while also providing technical references and resources for further assistance. Developers of environmental documents, such as Environmental and Social Impact Assessments (ESIAs), Environmental Assessments (EAs), IEEs, Environmental Review Checklists (ERCs), Environmental Review Forms (ERFs), and EMMPs for USAID projects or activities, will benefit from referring to this SEG throughout the project life cycle to improve compliance with applicable environmental requirements. However, document developers also should consult with host country authorities to understand local laws, regulations, and capabilities related to environmental compliance for road projects.

During project planning and design, potential environmental and social impacts should be identified and evaluated to adequately consider feasibility and mitigation measures before conducting any activities, including procurement. Such considerations may result in a change in project design early on to help mitigate environmental and social impacts before they occur, ultimately encouraging more sustainable road interventions around the world. Examples of project and activity design elements related to road projects, as well as how to mitigate potential impacts safely and effectively, are discussed in further detail in Sections 3 through 5.

# 2 OVERVIEW OF USAID ACTIVITIES IN THE ROADS SECTOR

Roads or road improvements are often proposed to solve one or more transportation problems, such as access, congestion, excessive travel times, or intermittent impassability. Roads are designed for a specific service level, such as the number of vehicles per hour, maximum vehicle weight limit, or travel speed. They also may be intended to serve a specific need (e.g., guaranteeing a reliable transportation route for perishable agricultural products during the peak harvest season, accessing tourist sites).

Although the transportation problem may be solved by other transportation methods (e.g., rail, boat, aircraft, pipeline), other vehicle choices (e.g., smaller trucks, buses, bicycles), or reducing peak traffic (e.g., staggered commuting hours, local post-harvest cold storage), this SEG begins when the decision has been made to evaluate the feasibility of building or upgrading a road.

## 2.1 ROADS SUPPORTED BY USAID

*Figure 1. Unpaved Trunk Road in Africa*

USAID may support a variety of project types in the road sector, from the rehabilitation or maintenance of existing roads to the construction of completely new roads. These roads may be designed to provide farmers access to markets; connect communities; provide access to economic opportunities or crucial social services, such as health care or schools; or, in some cases, improve access to or into protected areas to encourage tourism.

Many of the roads funded by USAID are low-volume, unpaved, rural roads (Figure 1); however, they also may be higher volume, multi-lane roads with durable pavement. The scope of the Roads SEG is intended to cover typical potential environmental impacts and mitigation measures for roads up to four-lane trunk roads and excluding limited-access highways and toll roads.

## 2.2 MANAGING THE ENVIRONMENTAL AND SOCIAL IMPACTS OF ROADS

Road improvements can bring substantial economic and social benefits to both local communities and national economies; however, the construction, use, and even the existence of roads also can lead to significant and long-lasting environmental damage. USAID's environmental procedures are designed to consider the potential adverse impacts from roads, to foster the use of best design practices to minimize adverse impacts, and to mitigate unavoidable impacts to minimize negative effects.

USAID takes a broad view of the environment and environmental impacts to ensure that environmental factors and values are integrated into USAID's decision-making process. Consistent with U.S. and international best practices, environmental evaluations include the consideration of physical impacts to air, soil, and water; impacts to natural resources; impacts to natural habitats, ecosystems, and threatened or endangered species; physical impacts to humans, including consideration of health and safety; social impacts that affect economic and community sustainability; and potential impacts from future climate change.

Furthermore, the environmental evaluations must consider direct, indirect, and cumulative impacts. Direct impacts are those that are caused by direct actions associated with the activity and that occur at the same time and in the same place as the action. A direct impact could be the clearing of vegetation and habitat in a sensitive environment, such as a wetland. Indirect impacts are caused by the action but occur later in time or at some distance from the action but are still reasonably foreseeable. Examples include future development following the construction of a new road or the spread of disease by insect vectors breeding in an abandoned, flooded quarry. Cumulative impacts are changes that result from the incremental impact of the action when added to the impacts from other past, present, and reasonably foreseeable future actions.

In order to manage the environmental impacts of road projects, the project team should do the following:

- Understand the physical, biological, and social setting for the road project;
- Define the physical activities, input materials, construction methods, and waste streams for the road project;
- Identify the environmental and social impacts of the road project activities; and
- Develop, implement, and monitor mitigation measures to avoid or minimize adverse impacts.

This document discusses each of these steps and presents details on typical road construction projects, common environmental impacts, and best management practices for mitigating the potential impacts during project design and implementation.

Where impacts are identified, it is necessary to work though possible mitigation and enhancement measures to manage the impacts to acceptable levels. "Mitigation" is defined in the National Environmental Policy Act (NEPA) implementing regulations (40 CFR 1508.1(s)) as measures that include the following actions:

- Avoiding the impact altogether by not taking a certain action or parts of an action;
- Minimizing impacts by limiting the degree or magnitude of the action and its implementation;
- Rectifying the impact by repairing, rehabilitating, or restoring the affected environment;
- Reducing or eliminating the impact over time by preservation and maintenance operations during the life of the action; and
- Compensating for the impact by replacing or providing substitute resources or environments.

Mitigation options should be applied by adopting the "impact mitigation hierarchy" concept (Figure 2) (USAID 2017). Project designers and implementers should consider the application of mitigation approaches in the following order of preference: avoid, minimize, rectify, reduce over time, and compensate for project impacts.

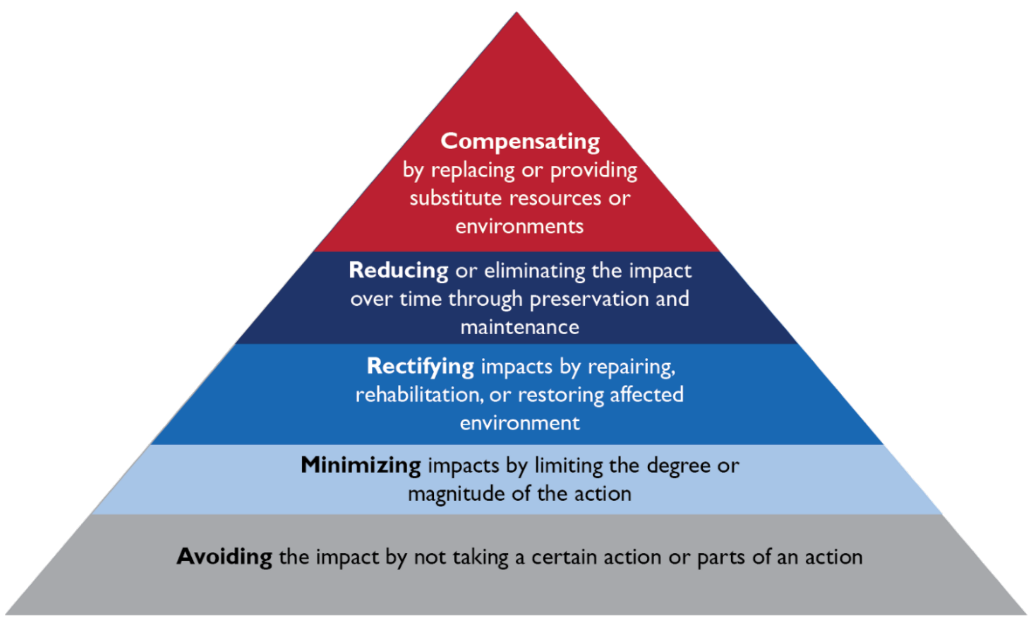


*Figure 2. Impact Mitigation Hierarchy*

# 3 ROAD CONSTRUCTION AND OPERATION

This section describes the methods, materials, and equipment typically used to construct and maintain roads. Road projects will include all or a subset of the components discussed. An environmental evaluation should consider the components applicable to the specific project in order to understand the physical activities, input materials, construction methods and equipment, and waste streams for that road project that may have adverse environmental impacts.

## 3.1 PLANNING AND DESIGN

Minimizing adverse environmental impacts begins in the planning and design phase. Careful siting, thoughtful choice of design parameters, and the inclusion of environmentally protective design elements can avoid or minimize detrimental impacts from roads.

### 3.1.1 GENERAL DESIGN CONSIDERATIONS

General design considerations encompass the fundamental service parameters of a proposed road, which relate to the transportation problem(s) the road is being proposed to solve. The service parameters typically include the endpoints of the road, one or more intermediate waypoints, design traffic volume, maximum vehicle weight, and travel speed.

General design considerations also include the design envelope, which establishes the conditions that the design must meet. The design envelope considers all the service parameters; the expected service life; and the revenue and organizational capacity available to build, operate, and maintain the road. The design envelope also includes the types and magnitudes of external forces or conditions that the road is designed to experience, to survive, and, in many cases, to remain in service while under those conditions. These conditions may include temperature extremes, precipitation, flooding, wind, and earthquakes.

### 3.1.2 CLIMATE CHANGE CONSIDERATIONS

Because the service life of a road is measured in decades or longer, the design weather extremes and climate conditions must consider the potential for climate change to alter the frequency, duration, or magnitude of extreme weather events and climate changes projected over the service life of the road. Higher extreme temperatures can induce softening or buckling of pavement, distortions at bridge abutments, and desiccation and shrinkage of soils leading to differential settlement. Extreme cold temperatures may cause conditions that need to be considered in the design to address reduced road friction; frost heaves; potholes; ice formation and obstruction in drainage systems; material embrittlement; and mechanical or electrical failure of safety devices, such as crossing gates or traffic lights. High winds can damage signage, signals, and supporting poles and wind-generated dust can impair visibility and limit sight lines. High or sustained winds can also cause the migration of sand dunes, resulting in road blockage.

The most important climate-related parameter that needs to be evaluated is often precipitation. Increases in the amount, frequency, or intensity of precipitation can overwhelm drainage systems if the design does not account for the increases. Inadequate drainage systems can lead to immediate damage from flooding and soil erosion. Over a longer term, higher groundwater levels, saturation of the road base, and water beneath the pavement can shorten the lifespan of the road due to rutting,[1] pothole formation, and pavement failure. Changes in soil moisture and groundwater levels from increased precipitation can trigger soil erosion, mudslides, debris flows, or landslides that damage or block roads.

Increases in precipitation can also increase the frequency or elevation of floods. This may require raising the design elevation of the road or bridges and modifying the number and designs of culverts and bridges to prevent sections of the road from flooding.

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[1] “Rutting” is the formation of longitudinal surface depressions or ruts in the road along the tracks of vehicle wheels.

Extended periods of drought can lead to insect infestations and tree mortality, followed by wildfires. Extreme temperatures worsen the wildfire conditions. If a burn area is later hit with a moderate to intense rainfall event, the unprotected soil is more susceptible to soil erosion, mudslides, debris flows, or landslides.

In addition to evaluating the impacts of potential changes to the climate in the geographic area of the road project, designers also may need to consider impacts caused by climate change at distant locations. For example, melting of the Greenland or Antarctic ice sheets or warming of the oceans may lead to sea level rise or increased flooding from storm surge that impacts siting decisions, stability of coastal bluffs, or drainage of stormwaters to the sea.

Climate change impacts can be addressed by expanding the design envelope to include the potential external conditions that may occur over the lifespan of the road, by designing the road components to withstand those conditions, by designing resilient systems so that the road can tolerate local failures that do not degrade the road below the required service level, by building redundant road systems with alternate routes, and by adopting an adaptive management approach.

Designers also should consider the potential impacts of the design, construction, and operation of the proposed road on the climate. Alignment alternatives might reduce the need for vegetation removal or result in an alignment requiring less energy use during operation by incorporating gentler grades and fewer changes in elevation. Project specifications can specify construction materials that produce lower greenhouse gas emissions during their manufacture and transport.

During construction, greenhouse gas emissions can be reduced by maximizing the energy efficiency of the internal combustion or electrical equipment used for construction and by using energy-efficient equipment in offices, camps, or workshops.

USAID project and activity design teams are required to identify any moderate or high climate risks and either address them by developing risk management measures or document any accepted climate risks. Automated Directives System (ADS) references ADS 201mal Climate Risk Management for USAID Projects and Activities and ADS 201mat Climate Change in USAID Country/Regional Strategies provide additional climate risk guidance.

#### 3.1.3 SITING

Siting a road is largely constrained by the endpoints of the road and any intermediate waypoints. The road alignment may deviate from the shortest distance option of straight-line segments to account for geographic features such as changes in elevation, water bodies, or difficult ground conditions such as marshy ground or rocky areas; to avoid having to acquire land in densely populated areas; or to avoid disturbing sensitive ecological habitats or migration corridors.

Siting studies should also identify areas that ought to remain road-free through undertaking a global zoning exercise. This identification promotes roads and road development in areas such as those that contain existing rural development and can increase agricultural yields, while at the same time limiting roads where the prospects for environmental damage are great (Laurance, Clements, et al. 2014).

Roads are commonly sited in areas with gentle topographic relief, along river valleys, or along ridgelines. These alignments limit the maximum incline and decline of the road, minimize repeated climbs and descents that increase operating costs, and avoid the need for switchbacks that greatly increase the length of the road. However, building roads in river floodplains should be avoided due to the potential for flooding. The location of the road should have sufficient grade to effectively carry stormwater away from the road.

Surface water bodies may need to be crossed or circumvented. A river can be crossed with a bridge or ford, but the optimum crossing site may not align with the preferred road alignment. A lake can sometimes be crossed with a causeway or bridge; however, if the water is deep or the foundation conditions are poor, the road may need to pass around the lake.

Road alignments should avoid disturbing sensitive ecological habitats, such as wetlands and forests, not only by avoiding or minimizing direct destruction of the habitat by the construction or existence of the road, but also by recognizing other types of potential disturbance. Siting decisions should consider establishing buffer zones between a road and sensitive habitats to protect the habitat from road noise and light and from encroachment by road-induced development. Protected areas and wildlife migration corridors should also be mapped and considered when planning the road alignment.

In areas with aesthetically, economically, or culturally important scenic views, siting decisions should seek to integrate the road into the landscape in the least intrusive manner possible.

### 3.1.4 PRE-CONSTRUCTION STUDIES

During the feasibility stage of a road project, topographical, engineering, geotechnical, hydrological, biological, ecological, archeological, paleontological, or social studies may be needed to gather information along potential alignments. The information is used to evaluate the constructability of the road and determine the availability of construction materials, such as soil, rock, and water. Studies may also involve mapping springs, rivers, and wetlands; floodplains; steep or unstable slopes; geologically difficult terrain; areas of high erosion potential; sites of historic, religious, or cultural significance; ecologically sensitive or important areas, such as tropical forests, habitat for threatened and endangered species, or other areas of high biodiversity; or high-carbon ecosystems, such as forests, mangroves, and peatlands, that sequester carbon and help reduce atmospheric carbon dioxide ($CO_2$) concentrations.

The studies themselves usually require observational field surveys that involve some level of physical intervention into the area of interest and possible collection of physical or biological samples. More intrusive investigations may involve activities with more direct impacts, such as geotechnical borings or excavations, to determine the suitability of existing soils or the adequacy of a potential borrow area or quarry. Existing geographic information system (GIS) databases may be available that include information on topography, soils, geology, vegetation types, population demographics, protected areas, and threatened and endangered species. Satellite imagery, such as from Google Earth, is useful for understanding land use along the potential road alignments.

The feasibility studies also need to consider the social aspects of the road construction and operation. Consultations with national, regional, or local leaders; local road authorities; local partners; and community groups can highlight legal, cultural, or demographic issues that may influence the design.

### 3.1.5 RIGHT-OF-WAY CORRIDOR

Once the general route of the road is determined, the right-of-way corridor must be defined. The right-of-way corridor is generally a strip of land that follows the planned alignment but is wider than the road itself and provides space for pedestrian walkways or bicycle paths, drainage features, and a safety zone between the road and built structures. The right-of-way corridor needs to include the anticipated width of the cut and fill slopes on each side of the road. In steep terrain, cut and fill slopes can add significant width to the road construction footprint. The right-of-way corridor often includes additional width to allow future expansion of the road. It also permits minor changes in the road alignment within the corridor for engineering, environmental, or cultural reasons without necessitating additional land acquisition outside of the right-of-way corridor. It is important for the project design team to have full understanding of land ownership and tenure along and adjacent to the right-of-way corridor to allow for appropriate planning and decision making during the planning and design phase.

The right-of-way corridor is physically marked in the field during project stakeout. During this stage, a survey crew would travel the entire length of the road project and physically install temporary or permanent markers to delineate the right-of-way corridor from adjacent land. Typically, land within the right-of-way corridor is owned by or acquired by a government entity. If land within the right-of-way corridor is privately owned or is, by custom, in private use, acquisition of the land would require negotiations with and likely compensation for the land or loss of land use. It may also require resettlement of residences or relocation of businesses from within the right-of-way corridor.

Establishment of the right-of-way corridor generally imposes legal restrictions on future private building within the corridor.

The road alignment encompasses the physical width of the road itself and potentially the road shoulders. The centerline of the alignment would usually be located along or near the centerline of the right-of-way corridor but may deviate within the corridor as the design is refined or if unanticipated conditions are encountered in the field.

During construction, the project owner will typically give the contractor control of the road alignment, as well as some additional land on both sides of the road within the right-of-way corridor for earthmoving activities, drainage structures, or other uses to facilitate construction. At the end of construction or when the contractor no longer needs the land along a section of the road, the contractor returns or hands over control of the land to the project owner.

#### 3.1.6 MATERIALS

Roads are generally constructed primarily of locally available materials to reduce transport distances and construction costs. The most common road construction materials are locally sourced soil and gravel. Higher quality roads may use bitumen (liquid asphalt) either as a soil binder or to make asphalt concrete, or use cement, either as a soil binder or to make concrete. Cement is also often used to make drainage structures, for stone masonry work, or for bridge abutments or foundations. Most of the roads funded by USAID are earthen or gravel roads. Asphalt concrete roads are also used on USAID co-funded projects. Concrete pavement is rarely used by USAID, except perhaps on bridge decks. All the materials used on road projects must meet the quality control and performance standards of the design specifications.

Rock or stone may be used as riprap[2] for erosion control or as a building material for masonry work for retaining walls, culvert wingwalls or headwalls, drainage channels, bridge abutments, or other components.

If reinforced concrete is used on the project, significant quantities of reinforcing steel, i.e., rebar, may be required (Figure 3).

*Figure 3. Placing Rebar for a Reinforced Concrete Bridge Pier*

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[2] "Riprap" is rock or other similar material used to protect against soil erosion from moving water.

Water is often overlooked as a necessary road construction material. Water is used to control the generation of dust from earthmoving activities and construction traffic and is used to make concrete. One of the largest water requirements can be the water necessary to increase the water content of soil to the proper moisture content for compaction, especially in hot or windy environments where soil can dry out quickly.

Construction of major roads often involves the use of motorized construction equipment, including earthmoving equipment, compactors, cranes, trucks, personnel vehicles, and electric generators. On large projects or projects in remote locations, the contractor may need to arrange for the supply and storage of significant amounts of gasoline and diesel fuel.

Construction may also involve the storage and use of hazardous materials other than fuels. Hazardous materials could include motor oils, lubricants, hydraulic fluids, greases, paints, adhesives, combustible welding gases, and a variety of specialty products and chemicals used in workshops.

Material sourcing decisions should consider environmental impacts. For example, if an otherwise ideal quarry is located within a sensitive ecological habitat or protected area, the environmental impacts may exclude it from further consideration. Stone or gravel extracted from a riverbed without adequate environmental safeguards may cause ecological damage or disrupt a surface water supply. The selected road materials must meet the engineering requirements of the design, including any extreme weather conditions within the design envelope or the potential for periodic flooding.

Other material selection and sourcing considerations could include the energy required for extraction and transportation, which has both financial and climate impact considerations, and potential material substitutions that may avoid or reduce some impacts, including using lower grade or recycled materials or materials with a lower carbon footprint. The project should evaluate backup sources in case the original sources cannot meet the demand because the projected available supply was overestimated, the requirements increase due to field changes, or material testing disqualifies material from the original source. Material selection should also consider the material needs for maintenance over the service life of the road.

#### 3.1.7 CONTRACT CONSIDERATIONS

Prior to the initiation of a road project, there should be an environmental review to assess the potential significant adverse environmental impacts, develop mitigation measures, and establish a monitoring plan. The environmental review may vary from a simple screening of potential impacts to a more formal Environmental Assessment or an Environmental Impact Assessment, depending on the project complexity, size, and likely impacts. An EMMP should specify what needs to be done, where it needs to be done, when and how the actions will take place, who is responsible, and how compliance will be monitored and reported.

Once environmental safeguard requirements are established, they need to be incorporated into the contract documents so that they are implemented by the parties responsible. The environmental safeguards may be included in the technical specifications as discrete elements to be constructed or may appear in the technical specifications as required procedures or best practices for certain activities, especially if the environmental review is conducted in collaboration with the project design engineers. The safeguards may be subject to field instructions to prevent unsatisfactory conditions or to ameliorate defects discovered during site inspections, such as by including contract language similar to "… or as directed by the engineer." In all cases, the contract documents must clearly state the requirements and include enforcement mechanisms to encourage contractor cooperation and compliance.

It may not always be possible to develop the final EMMP prior to contract award. On large projects, a contract-level EMMP will often be developed that covers the essential areas of concern and includes typical mitigation measures but does not have the level of detail for enforcement in the field. For example, it may be known that the road project will require quarries and road detours; however, the specific locations may be decided later by the contractor. In such cases, common practice is to require the contractor to develop a site-specific EMMP for any sites or activities not explicitly covered in the contract documents.

Obtaining satisfactory contractor compliance to address environmental issues can be a challenge, especially if the contractor perceives the requirements as regulatory “add-ons” and not as components of the “real work” of building a road. It is important that the contract incentives and enforcement mechanisms are well balanced. Contractors have been known to minimize or avoid their environmental requirements either because there is no corresponding pay item or because the pay item is too small to encourage them to comply. Alternatively, if the unit pay rate is too generous, the contractor may try to increase its profitability by installing more silt fencing and riprap than is needed. It can be contractually difficult to force compliance and there is a danger that a contractor could use any work stoppages as justification to file expensive delay claims.

Several techniques have been used to elicit better contractor cooperation. Integrating environmental requirements into the design as construction components makes those components part of the regular workflow and tends to encourage inclusion of those line items in the contractor’s work schedules.

On large sites, the contractor may not be given authorization to proceed across the entire site at one time. For example, it would not be advisable to allow a contractor to clear vegetation along the entire road alignment if it would take months or years for the subsequent construction processes to reach those areas. If there is a formal approval process for authorization to proceed, one of the conditions for approval could be that all required environmental mitigation measures are in place. If the required environmental conditions have not been met, the owner’s representative, such as an engineer or engineering firm overseeing construction, would not authorize work in that specific area. This aligns the contractor’s incentive to proceed (and get paid) quickly with the need to have the mitigation measures in place. This approach is similar to industry practice for safety measures, e.g., if workers do not have appropriate personal protective equipment (PPE) then work cannot begin. If the requisite environmental controls are not in place, e.g., silt fencing or secondary containment, the contractor cannot proceed. This approach also integrates environmental compliance into the standard approval process for moving the project forward and avoids making it a separate process.

The contract language and the project management team should carefully consider what actions can and will be taken if the contractor repeatedly defaults on its environmental responsibilities. Non-payment of a very small percentage of the contract price is a poor outcome if the project leaves extensive environmental damage in its wake. The responsibilities and authorities of USAID and IP personnel should be clearly defined and reviewed by legal counsel to minimize the risk of contractor claims.

## 3.2 MOBILIZATION

Many temporary components of a road project are not part of the finished project but have environmental and social impacts before and during construction of the road. This section describes many of these components to facilitate consideration of their potential impacts.

### 3.2.1 FIELD OFFICES

On most road projects, the contractor will set up a field office at or near the construction site. For small projects, this may be an on-site field trailer or nearby rented office space. On larger, long-term projects in remote areas, the contractor may erect temporary prefabricated buildings or may build dedicated offices for the engineering staff, inspectors, technicians, environmental staff, finance personnel, human resources personnel, and others (Figure 4). An owner’s technical representative may have his or her own office space on or near the site. The engineer’s offices may include facilities, such as a soils and materials laboratory, to perform independent quality assurance and quality control tests. At the end of road construction, field trailers and prefabricated buildings would normally be removed. Any newly constructed buildings may be handed over to local or regional authorities for use as government offices, schools, or other community uses. The final disposition of any newly constructed offices should be considered in their design so that they can best serve their long-term function.

Construction or installation of a field office may involve clearing and grubbing[3] the office site, transporting the offices or office construction materials, and managing the construction or installation process and its impacts. On-site offices require washing and sanitation facilities, which could range from a water tank and portable toilets to drilled water wells, several multi-person bathrooms, and a full septic system. Depending on the scale and location of the field offices, setting up the offices may also involve the construction of access roads, driveways, and vehicle parking areas.

*Figure 4. Field Offices and Construction Camps*

### 3.2.2 CONSTRUCTION CAMPS

The on-site personnel involved in road projects require food, housing, and satisfactory living conditions. For a small project in a populated area, such as regrading the main, unpaved, compacted earth road through a village, the labor force may be local and eat and sleep where they normally would. On larger projects, the available housing in an area may not be sufficient in quantity or adequate in quality to support an outside labor force, thereby requiring the construction of new temporary or permanent housing. On very large projects or projects in remote areas, the construction camps may need to be self-sustaining and provide not only housing but also their own food, water, sanitation, power, fuel, communications, dining facilities, and recreational facilities. There may be separate camps or separate housing arrangements for the owner's engineering team, the contractor's professional staff, the contractor's skilled staff, and the general labor force. Much of the general labor force can be hired from the local population and live at home, but skilled equipment operators, specialty trades, and experienced forepersons may be from out of the area and need housing.

### 3.2.3 WORKSHOPS

Except on the simplest road projects, the contractor will have multiple vehicles, earthmoving equipment, generators, pumps, compaction equipment, and other mechanical equipment. Much of the equipment will have internal combustion engines. The contractor will need to maintain this equipment in good working order throughout construction and much of this maintenance will take place on site.

The contractor will usually have someone on site who can perform routine maintenance and make minor repairs, sometimes the equipment operator himself or herself. On small projects near population

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[3] Clearing refers to the removal and disposal of trees, shrubs, and similar vegetation. Grubbing refers to the removal and disposal of grasses and subsurface roots.

centers, the contractor may be able to rely, at least in part, on commercial mechanics for more complex repairs. On larger projects, especially in remote areas, the contractor will usually have one or more full-time mechanics and a dedicated workshop area.

For ad hoc repairs or routine maintenance, equipment may be serviced in the field to avoid driving or transporting the equipment to a workshop. Routine maintenance may involve changing motor oil, gearbox oils, and hydraulic fluids, as well as the oil filters and hydraulic hoses. In the field, drip pans should be used to prevent soil or water contamination. In a workshop, work areas should be designed to prevent accidental releases of oils and other hydrocarbons, generally by working on a concrete pad with spill control features. All used oils should be collected and stored on site until they can be recycled.

Other hazardous materials associated with vehicles and equipment include gasoline, diesel fuel, solvents, paint, lubricants, and greases. Workshops may have oxyacetylene cutting torches and their associated cylinders for acetylene and oxygen gas, as well as smaller propane, butane, or other gas torches. Rags used to wipe up fuel or oils are both a pollution and a fire hazard and must be considered hazardous.

The number and size of workshops depend on the size of the road project. Shipping containers can often be used or modified to make workshops or workshop storage space.

### 3.2.4 FUEL STORAGE AREAS

Logistically, fuel is one of the most important commodities on a construction site and a reliable supply is paramount for the contractor to maintain productivity. On a small project near a population center, the contractor may be able to transport fuel from a commercial fuel station to the project site using a tank in the bed of a pickup truck or a small tanker. On large or remote projects, the contractor may need to build a fueling station at the contractor's camp (Figure 5).

Aboveground tanks on concrete pads with secondary containment provide the most visible assurance that the fuel tanks are not leaking; however, sometimes underground tanks will be preferred for security reasons. Underground tanks may be directly buried double-wall tanks or single-wall tanks in a watertight vault. Underground tanks may not be suitable in areas of high groundwater, permeable soils, or proximity to surface water or drinking water wells because of the risk of undetected leakage.

*Figure 5. Fuel Storage Tanks with Bund Wall*

Secondary containment for spill prevention and control is required anywhere that fuels or oils will be stored, including waste oils. Secondary containment could be something as simple as a metal pan under a generator or a more complex enclosure such as a cast-in-place concrete slab surrounded by vertical concrete walls. The secondary containment structure should be designed to contain a volume greater than the maximum possible spill, e.g., the volume of a storage tank plus any interconnected tanks and associated piping. Containment structures located outdoors typically have a valve to drain clean, accumulated rainwater. The valve must normally be in a closed position, otherwise the secondary containment will be ineffective. For underground storage tanks, double-walled tanks are now the industry standard and provide integral secondary containment.

### 3.2.5 LAYDOWN AREAS AND WAREHOUSES

Laydown areas are simply flat open areas where the contractor can store construction materials and components, such as structural elements, rebar, pipe, culverts, bridge girders, precast manholes, curbstones, or other items that can withstand the weather (Figure 6).

The size of the laydown area, and therefore the amount of land that will need to be cleared, grubbed, possibly graded, and possibly prepared with a gravel bed, depends on the size of the road project. On a large project, the laydown area(s) can easily require several hectares of land.

Materials that need to be protected from the weather may be stored in warehouses. Temporary warehouses are often simple steel-framed buildings with metal siding but may vary based on local building materials and practice.

*Figure 6. Material Laydown Area*

### 3.2.6 BORROW PITS

Borrow pit refers to a site from which clay, sand, gravel, or other soil is excavated for use in a construction project. Use of a borrow pit is distinct from the soil cut-and-fill balancing that occurs during grading within the road alignment itself. A borrow pit may be temporary in nature and used for a single project or may be a large, ongoing, commercial venture. For most USAID road projects, borrow pits will be temporary.

A feasibility study may have been done during the planning and design phase to determine the likelihood that needed soil materials would be available in the area, but the number, location, and size of borrow pits may not be known before construction begins. Borrow pits may be outside of the right-of-way corridor on land not owned by the project owner. Common practice is for the contractor to identify the specific locations for the borrow pits needed and to negotiate with the landowner or government entity for access to the site and for the volume of material extracted.

Mismanaged borrow pits can leave ugly scars on the landscape, cause soil erosion and sediment-laden runoff that degrades nearby surface waters, trap water that breeds disease-transmitting insects, or present drowning hazards to small children. To avoid those outcomes, a borrow pit management plan should include measures to segregate and conserve removed topsoil, manage water run-on and runoff during operation, prevent unnecessary erosion, prevent sediment transport by using silt fencing or other means, and control site access with signage, security fencing, and public education.

*Figure 7. Borrow Pit*

Commonly, one or more front-end loaders or excavators will work within the borrow pit excavating the soil and filling dump trucks (Figure 7). A bulldozer or excavator may aid in excavation, especially if the in-situ soil is stiff or contains large rocks. On large projects, the arrival and departure of trucks may be nearly nonstop, and, consequently, the impacts of the truck traffic must be considered along the entire route between the borrow pit and the point of soil use along the alignment.

A site restoration plan should be agreed to with the landowner for implementation when the borrow pit is no longer needed. Although the general elements of the plan should be established during negotiations for use of the land, the details of the restoration plan will be defined after the limits of excavation are known.

#### 3.2.7 QUARRIES

Quarries differ from borrow pits in that they generally involve the extraction of rock instead of soil. Although some quarries may involve the excavation of loose stone, the term most often refers to the exploitation and processing of intact rock. Road construction can require large quantities of good quality rock for road base material, road surfacing, concrete aggregate, drainage applications, and erosion protection. Typical quarry operations include drilling, blasting, excavation, transport, rock crushing, screening, stockpiling, and truck loading (Figure 8).

Like borrow pits, quarries may be located on land not controlled by the project owner, may have been tentatively identified during a feasibility study, and may require negotiations with and compensation to a third-party landowner. A quarry area often requires at least a few hectares of land but can be much larger. As required for borrow pits, the contractor should develop a management plan that describes how the quarry will be developed, what environmental safeguards will be in place during its operation, and how the quarry site will be reinstated at the end of construction.

Compared with borrow pits, quarries have some additional environmental and social impacts and risks. Safety protocols should be established to minimize risks from falling rock or debris, collapsing quarry walls, or accidental falls from cliffs. Water-filled quarry pits can lead to the drowning of humans, livestock, or other animals.

Whereas soil usually contains some water, quarried rock is typically dry and therefore generates more dust. The quarry operations involve breaking the intact rock into smaller and smaller pieces using explosives, hydraulic or pneumatic jackhammers, and rock crushers. The rock is loaded, moved, unloaded, dumped, stockpiled, and reloaded multiple times. All of the preceding operations can produce large quantities of dust, so dust suppression water systems are used to reduce dust levels.

*Figure 8. Rock Quarry*

Blasting has obvious safety hazards and requires the use of trained personnel, rigorous safety protocols, and strict security controls. Storage areas for explosives must be designed to limit the effects of accidental explosions, often by isolating the storage area and surrounding the storage vault with an earthen berm.

Rock crushing and processing equipment (Figure 9) requires a significant amount of energy. Crushers and material conveyors often operate on electricity, which can be supplied from the electrical grid if a connection is available. At a remote site, the crusher would be powered directly by a diesel engine or by electricity from one or more large diesel generators, either of which would require a reliable diesel fuel supply and a fuel storage location with proper engineering and environmental controls.

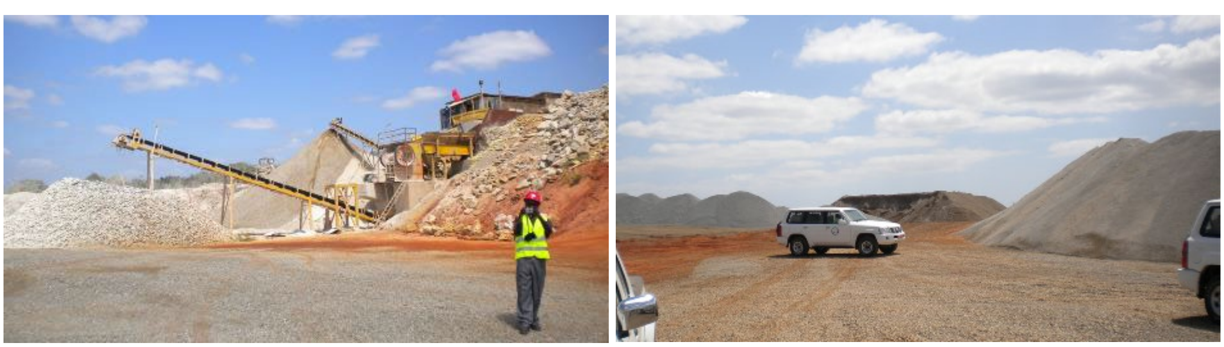

*Figure 9. Rock Crushing Operations*

Rock crushers are powerful machines with large mechanical jaws, impact rams, cone crushers, or other crushing mechanisms that can pose lethal risks to personnel if safety protocols are not followed, especially when clearing rock feed jams. A quarry may employ multiple crushers in a circuit to progressively reduce the rock size to the material size needed. Primary crushers can accommodate rocks larger than 1 meter in diameter, with their output providing input for secondary and tertiary crushers as the product is reduced to the size needed. Screening equipment is used to sort the product by size to obtain the gradation required. The crushed rock often moves among crushers, screeners, and stockpiles by belt conveyors, but can also be hauled by truck (Figure 10).

*Figure 10. Stockpiling Crushed Rock*

For smaller projects, portable rock crushers, conveyor systems, and screeners can be mobilized to the site. As an alternative to a conveyor system, material can be moved by front-end loader. At the extreme end of the spectrum, aggregate is sometimes broken down to the correct size by manual laborers using hammers – a method that was state of the art in the early 19th century according to John McAdam.[4]

> *The only proper method of breaking stones, both for effect and economy, is by persons sitting; the stones are to be placed in small heaps, and women, boys, or old men past hard labour must sit down with small hammers and break them, so as none shall exceed six ounces in weight. (McAdam 1821)*

Authors and reviewers of this SEG have personally witnessed contemporary examples of this in India, Malawi, Mozambique, Sudan, and Tanzania. In Malawi, a representative of a highway department reported that the department purchased aggregate from individual rock breakers on some projects. In Tanzania, rock breakers—including women and children—moved into closed rock quarries to produce aggregate after the contractors ceased quarry operations.[5]

Aggregate, especially rounded rock, also can be found in riverbeds or along riverbanks. If properly sized, this rock can sometimes be used directly (e.g., as erosion protection or as an energy dissipator at a drainage outfall). Rounded rock is generally not considered suitable for road base, surfacing material, or

[4] John McAdam revolutionized modern roadbuilding. His name lives on in the alternative names for asphalt pavement, "macadam" and "tarmac".
[5] USAID and its Implementing Partners must be aware of local labor practices and ensure that adequate safeguards are in place to prevent the use of child labor, including by subcontractors and material suppliers.

in concrete, but it can be crushed to create angular aggregate. On some projects, the use of rounded rock without crushing may be the most feasible alternative, despite its lower frictional strength. Exploiting rock deposits from within or along a river may require permits or be prohibited in some jurisdictions because it can adversely impact water flow, increase sediment transport, and disturb aquatic habitats. Limiting removal of aggregate from riverbeds or riverbanks to periods of low water, to locations well above the water line, and to old or historic river terrace deposits away from or above the active river can help reduce adverse impacts.

The sourcing of aggregate materials, e.g., sand and gravel, should avoid use of any prohibited sites. The operation of quarries and borrow pits, as well as extraction of gravel from rivers, should be conducted in strict accordance with governing regulations and the conditions of any permit or license issued by the appropriate national or local authorities.

### 3.2.8 TEMPORARY ACCESS ROADS AND HAUL ROADS

The field offices, construction camps, workshops, laydown areas, borrow pits, and quarries may be developed on land that was not previously accessible by road. Temporary access roads and haul roads that can support the volume and weight of the construction traffic, especially dump trucks loaded with soil or rock, are needed to connect these facilities to the construction in the right-of-way corridor. The establishment of these roads typically involves clearing and grubbing, loss of vegetation, removal of topsoil, increased potential for soil erosion, and changes to drainage.

Some temporary roads also may be needed to reach otherwise inaccessible sites, such as for drill rig access for soil and rock sampling during feasibility studies or to provide construction access to the lower part of bridge support columns, bridge abutments, or retaining walls.

### 3.2.9 WATER SUPPLY

Road construction frequently requires large quantities of water to adjust the compaction water content of soils; to suppress dust along haul roads, during earthmoving operations, and at borrow pits and quarries; and for concrete work. Potable water is also needed to support the workforce in the field and at camps.

*Figure 11. Water Pump Filling Cistern Truck*

Water is typically pumped from surface water bodies into water bowsers or tank trucks. Diesel pumps are often stationed at the water's edge to fill arriving trucks (Figure 11). The pumps should have secondary containment to prevent fuel spills and oil leaks from contaminating the water.

For dust suppression along roads, the trucks are commonly fitted with a spreader bar across the rear of the truck, which distributes a spray behind the truck by gravity or using a pump. The amount of water required along transportation routes depends on the weather conditions, the road surface, the traffic intensity, and the surrounding population. Hot, dry weather, road surfaces with a high percentage of fines, roads passing through populated areas, and roads with more traffic require more frequent watering and greater water use. In very dry areas where water is too scarce or too expensive to use for dust suppression, the contractor may elect to apply a binding agent on the roads to limit the release of fine soil particles.

Water supplied from wells may be of higher quality than surface water and require less treatment to meet drinking water standards. A camp is likely to have at least one water supply well and a simple filtration and disinfection system to provide potable water.

Water use on a road project should not overly burden the local water supply. If water is scarce or if the area is experiencing drought conditions, the contractor should not be allowed to extract so much water that there is not enough to support the local population's water requirements, including for agriculture, or to reduce stream flow below the ecological minimum required flow.

### 3.2.10 POWER

Field offices, construction camps, workshops, and quarries all require electric power. If reliable power is available from the grid for fixed locations, it can be a simpler alternative than generating on-site power. However, for backup power, mobile locations, and where grid electricity is not available, diesel-powered generators are the norm. Wherever diesel fuel is used, secondary containment engineering controls and spill response procedures should be implemented.

Solar photovoltaic installations may be used in some locations for some lighting or communications but are unlikely to meet all project needs.

### 3.2.11 COMMUNICATIONS

A system that allows for instant communication along the entire length of a road project has obvious efficiency benefits and important safety benefits in case of an injury, fire, or other emergency. However, on small projects, communication may be as basic as driving to each active work site periodically to check in with the work supervisors.

Communications requirements for road projects can include telephone, radio, and internet access. Even in remote locations, mobile phone use is increasingly available as a field communication option, although it may be limited to just voice and text, not data, in many places. Basic two-way radios have a range of up to 6 miles. Neither of the above solutions require any special infrastructure, even power, because they can be powered by a vehicle electrical system.

On longer road projects in areas without mobile data technology, the contractor may decide to install a radio system with a base station, together with an elevated antenna and repeaters. Such systems can reach up to 50 miles. Mobile network operators can also work with contractors to provide mobile network infrastructure at camps or along the road alignment to provide more robust service, including internet access. The potential environmental impacts of constructing the infrastructure for a radio base station or for extending the mobile network are not significant. Extending the telephone or data network for use on a road project can have significant social benefits if it improves access for the public and remains in place upon project completion.

### 3.2.12 SUPPLY CHAIN

A road project involves many materials, components, and pieces of equipment. The materials, components, and equipment should be sourced responsibly. For example, aggregate should be obtained from authorized sources with proper environmental safeguards, water use should not create shortages for the local population, and hazardous material selection and use may need to meet standards beyond the host country's requirements so as not to pose an unacceptable risk.

USAID-funded projects may face additional restrictions due to embargoes against or sanctions on individual countries. For example, on a U.S. government-funded road project in Africa, the contractor imported thousands of barrels of liquid asphalt. The barrels had been intentionally mislabeled to hide the country of origin, against which there were sanctions prohibiting the purchase or use of its products. All the asphalt was rejected, and the barrels had to be removed from the site. The additional handling, including management of leaking barrels, had environmental impacts and contributed to construction delays until replacement asphalt was sourced and delivered.

### 3.2.13 SECURITY

Construction sites have valuable materials that may be targets for thieves. In particular, cement, steel, and fuel may be stolen and resold. Small or trailer-mounted, easily transportable construction equipment, such as pumps and generators, are frequent targets of thieves. Out-of-area workers or expatriates may be targets for robbery or more serious violent crimes.

The security infrastructure at camps typically includes perimeter fencing with controlled access through a gate managed by security staff. The perimeter may need security lighting at night. Some contractors also have used electrified fencing, double-layered fencing, guard dogs, or a deep perimeter trench outside of the fence line to deter intruders.

In addition to safeguards against criminal activity, high-visibility infrastructure projects may be targets for social or economic protests. For example, the importation of an outside workforce may lead to protests to increase local employment on the project. Stakeholder consultation prior to project implementation can help minimize such social impacts by building project support with the local community, local leaders, and local law enforcement.

## 3.3 CONSTRUCTION

Many of the most significant potential environmental and social impacts of a road project occur as a result of the construction[6] process itself. To understand the potential impacts, one must understand the construction process. This section describes the materials and processes involved in constructing components of the road.

### 3.3.1 TRAFFIC MANAGEMENT

Regardless of whether the road project is a new road or an upgrade of an existing road, the project will disrupt the flow of pedestrian and vehicle traffic along and across the alignment. Even where no previous road existed, there may be paths along or parallel to the alignment that are used by an occasional off-road vehicle, animal-drawn conveyances, bicycles, or pedestrians. There is almost certainly vehicle, pedestrian, and domesticated animal traffic that crosses the road alignment at multiple points. Construction operations need to be designed to reduce any disruption of the normal traffic to acceptable levels while maintaining safe conditions for workers and the public.

Work zone intrusions frequently lead to worker injuries or fatalities. They also endanger vehicle operators and occupants if involved in a crash due to rough surfaces, open excavations, obstructions, or construction equipment. To minimize conflicts during construction, construction vehicles, equipment, and personnel should be physically separated from non-construction traffic and pedestrians. This can be accomplished on an existing road either by closing the full width of the road in active work zones and providing detours or by closing part of the road width in active work zones and managing bidirectional traffic on the other half. In Figure 12, traffic on the left is traveling on previously compacted road layers and traffic on the right is traveling on a detour along the side of the road while construction is underway on half the road width.

If detours are on land that is within the right-of-way owned by the project owner and handed over to the contractor, the contractor has greater flexibility in arranging the construction and detoured traffic. Otherwise, the contractor may need to negotiate the use of private land with landowners or obtain permission from local officials to detour traffic onto alternate roads.

Detours have potential land use impacts similar to other road-building activities such as clearing and grubbing, loss of vegetation, soil erosion, and changes to drainage. When the detours are no longer needed, they must be restored to a condition acceptable to the landowner and to USAID. This may include performing maintenance on non-project roads or revegetating natural areas.

If bidirectional traffic is maintained on the road during construction, lane reductions or width restrictions may allow simultaneous bidirectional traffic on larger roads. However, on smaller roads, traffic flow will more commonly be reduced to alternating directions within a single travel lane.

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[6] From ADS 201maw: "Construction: For purposes of this policy means: construction, alteration, or repair (including dredging and excavation) of buildings, structures, or other real property and includes, without limitation, improvements, renovation, alteration, and refurbishment. The term includes, without limitation, roads, power plants, buildings, bridges, water treatment facilities, and vertical structures."


*Figure 12. Half-Width Road Construction*

Mitigation measures include providing advanced notice of planned construction work; installing adequate signage well ahead of the work zone to alert drivers; reducing speed limits near the work zone and along detours; clearly delineating the allowed traffic paths and isolating the work zones with high-visibility cones, barrels, or lights; and providing traffic control personnel with flags to clearly direct drivers and to help control speeds. When alternating bidirectional traffic patterns are used, the traffic control personnel may use reversible stop and go signs to direct traffic flow. They may need radios if the road section is too long for the flagmen at each end to see one another and communicate about vehicle passage.

In all cases, the traffic control personnel must wear high-visibility clothing. At night, the detours must remain clearly marked and may require warning lights and lighted signs.

Additional considerations for traffic close to construction zones or along detours include dust control, pedestrian safety, pedestrian crossings, and impacts on residents and businesses along detours. Impacts on businesses can include reduced access and loss of revenue, which may require compensation.

#### 3.3.2 EXISTING UTILITIES

Before any earthmoving activities begin in any area, the existing utilities must be identified, mapped, and located in the field. Utilities may need protection during construction, permanent relocation, or temporary relocation during construction with subsequent restoration.

Utilities may include electrical cables, communication cables, water lines, stormwater drainage pipes or structures, and sewage pipes. The electrical and communication lines may be aboveground on poles or below ground.

#### 3.3.3 CLEARING AND GRUBBING

Any vegetated area that will be the location for the road, detours, camps, workshops, laydown areas, borrow pits, quarries, temporary roads, or any other site required for construction will undergo clearing and grubbing. Clearing refers to the removal and disposal of trees, shrubs, and similar vegetation, including downed logs, branches, and brush. Grubbing refers to the removal and disposal of surface vegetation, stumps, and roots below ground level (U.S. Department of Defense 2022).

The need for tree and ground cover removal should be considered when planning the road alignment, with a preference given for alignments that conserve trees and minimize the loss of vegetation from clearing and grubbing operations. For acquisition of or temporary use of private land, the values of existing trees should be included in the calculations of compensation to landowners. If the road project requires the permanent removal of trees, the impacts can be partially mitigated by planting new trees nearby. The timing of clearing should consider the potential impacts on nesting birds, bats, or other species.

Clearing may be performed using tree saws, axes, or chainsaws; using powered cutting and grappling tools attached to mobile equipment; or using bulldozers. Grubbing is normally done by bulldozing or ripping the surface to remove roots and stumps. The material would then be moved manually or by grappling equipment, usually to the closest acceptable area to minimize haul time and expense.

Trees and other woody vegetation may have value as firewood for heating or cooking. Making the removed material available to the general public or to firewood distributors or charcoal manufacturers may reduce pressure on alternate wooded environments, offset other fuel sources, engender community goodwill, and reduce overall debris management costs. The remaining material can be chipped, composted, burned, buried, or left on the surface to decay. Burning would have air quality impacts by generating greenhouse gases and particulate matter and may not be the preferred option. Burial would remove the material from sight, but its decay would release greenhouse gases and potentially lead to land subsidence at the disposal site. Burying or leaving the material on the surface may encourage termite infestation where wood-eating termites are prevalent. Termites produce 3 to 4 percent of all methane, a potent greenhouse gas (Ho, et al. 2013). Leaving the cleared vegetation in brush piles on the surface may cause a temporary adverse visual impact but also may provide protective habitat for small wildlife.

Removal or control of vegetation with herbicides should be discouraged. Any use of herbicides must follow health and safety procedures to protect people and the environment, must be used according to the manufacturer's specifications. Herbicides are considered pesticides therefore any herbicide use may require preparation of and compliance with an approved Pesticide Evaluation Report and Safer Use Action Plan (PERSUAP).[7]

### 3.3.4 EARTHWORKS

Earthworks involve the excavation, transport, placement, and compaction of soil and rock. On small projects, where labor is inexpensive or where powered equipment is unavailable, earthworks may be undertaken manually using simple tools, such as shovels, picks, hoes, and tamping tools, with the soil transported by wheelbarrows, animal-drawn carts, or small trucks. On larger projects, earthmoving equipment such as front-end loaders, excavators, and bulldozers are used to excavate soil; trucks are used to transport soil; and front-end loaders, bulldozers, backhoes, and graders are used to spread soil. On some projects, motor scrapers can perform all three earthmoving functions—excavation, transportation, and spreading.

Topsoil, i.e., the fertile, vegetative surface layer of soil, is a valuable resource for the natural habitat, agricultural producers, and site restoration. Earthmoving operations should be performed in a manner that prevents loss of topsoil through soil erosion by water or wind. Before any excavation begins at a

[7] A Pesticide Evaluation Report and Safer Use Action Plan (PERSUAP) is required by 22 CFR 216.3(b)(1) for "all proposed projects involving assistance for the procurement or use, or both, of pesticides." ADS 312 Eligibility of Commodities defines a "pesticide" as "any substance or mixture of substances intended for preventing, destroying, repelling, or mitigating any unwanted insects, rodents, nematodes, fungi, weeds, and other forms of plant or animal life or viruses, bacteria, or other micro-organisms (except viruses, bacteria, or other micro-organisms infesting humans or live animals), or intended for use as a plant regulator, defoliant, or desiccant."

site and before any area is covered by fill, the topsoil layer should be removed and stockpiled for later reuse.

The majority of earthwork on a road project includes earth excavation (cuts) and placement (fills) to conform the land to the design road geometry. The cut-and-fill volumes are generally optimized during the project design to reduce the amount of excess soil generated by a project or the amount of soil needed to be brought in to establish the design elevations. In general, the design elevation should be higher than the surrounding land on at least one side of the road so that water can drain freely off the road.

Cuts may be needed to remove unsuitable soil or to lower the ground elevation. Cut slopes in soil should be designed to be stable and be able to support ground cover to avoid erosion. Cut slopes in rock or cemented soils can be steeper and can better withstand erosional forces without vegetation.

If excavated soil is unsuitable or too great in quantity for reuse as fill elsewhere, unusable soil may need to be permanently moved to a new location. The excess or unusable soil may be placed in spoil piles designed in a manner that conforms with the general landscape, will not cause adverse disruption to precipitation runoff, will not be easily eroded, and will not lead to the transport of sediment to nearby surface waters. The downslope side of the spoil piles should have silt fencing or other means to control sediment-laden runoff whenever the soil surface is bare. When the spoil pile reaches its final height and geometry, the soil should be vegetated to protect the pile from erosion.

Cuts also include excavation in rock. The drilling, blasting, excavation, truck loading, and transport processes for rock excavation are similar to those used in quarries.

Structural or engineered fill is placed in layers and compacted to achieve the required density and strength. This fill is placed in areas that need to be built up to the design grade using common fill but also can include the placement and compaction of subbase and base layers of the road itself. If the soil available from cuts is insufficient to reach the required grade, additional soil is obtained from borrow pits. Soil can be compacted using manual tampers consisting of metal plates attached to poles, which a laborer repeatedly lifts and drops; using walk-behind vibrating plate compactors; or using heavy, self-propelled drum or sheepsfoot rollers. The fill is spread and compacted in layers, typically about 15 centimeters (cm) thick if compacted with heavy equipment, but thinner if compacted by hand.

Regardless of the compaction method, the soil being compacted should be close to its optimum compaction water content to achieve the greatest density. Wet soils may need to be dried before compaction but more commonly water needs to be added to and mixed into the soil to obtain the proper water content. The compaction water requirements can be substantial and need to be addressed during project planning.

During cut-and-fill operations, there can be substantial truck traffic along the project road, along detours, along haul roads to and from borrow pits and quarries, and along other public roads. The truck traffic may cause adverse traffic, public safety, and air quality impacts. Dust generation from truck traffic may require the use of substantial quantities of additional water for dust control.

### 3.3.5 CONCRETE WORK

Many components of a road project may include working with cement or concrete.

Cement may be provided in individual bags or may be purchased in bulk. Even on very large projects, providing cement by the bag may have logistical advantages because the bags can be transported in smaller, common vehicles and loaded, unloaded, and otherwise moved by manual labor. Thousands of empty cement bags require proper waste management.

On large projects, the contractor may set up a concrete batching plant. The batching plant would generally have a cement bin or silo containing bulk cement, as well as other bins for aggregate, a water supply, conveyors, and mixing equipment. Bulk cement is transported in specialized trucks that may not be suitable for locations with poor-quality roads.

Cement or concrete work on road projects may be as minor as applying mortar to masonry blocks or as complex as manufacturing curbing, bridge beams, and hundreds of concrete pipe culverts in an on-site casting yard. It can involve formwork and placing reinforcing steel for cast-in-place structures, such as box culverts or abutment wingwalls (Figure 13).

Cement dust poses an inhalation hazard to workers and an environmental hazard to the surrounding habitat. Unlike dust originating from soil, cement dust cannot be controlled with a water spray. Workers must wear protective equipment for their eyes, nose, and mouth, typically protective goggles and dust masks. It is not uncommon for personnel working with dry cement to also wear hoods under their hardhats or to wrap their faces with additional layers of cloth, especially in windy conditions. Ambient cement dust can be controlled somewhat by engineering controls such as walls or partitions that act as windbreaks at the point where the cement bags are emptied. Dust from a cement silo can be more easily controlled by limiting the distance that the cement powder falls through open air at the point of discharge.

*Figure 13. Concrete Box Culvert Under Construction*

Wet cement has a pH of 12 to 13 and is very caustic. Contact with wet cement or concrete can cause skin irritation, dermatitis, chemical skin burns, and permanent scarring.

Cast-in-place reinforced concrete involves placing the reinforcing steel bars, known as rebar, at precise locations and orientations within a wooden or steel form. Working with reinforcing steel may involve working at heights. Falls can be particularly perilous if there are exposed ends of rebar in the fall zone. Before concrete is poured into the form, the interior surfaces of the form are coated with a release agent to facilitate the form's release after the concrete cures. Historically, the most common form release agent has been oil; however, some oils, such as diesel oil, may exceed the current, allowable limits on volatile organic compounds (VOCs). Where oil or oil-based release agents are used, their use must be controlled to limit spills, soil contamination, or water contamination, especially because much of the concrete work for culverts or bridges would be near surface water or drainage pathways.

Alternative concrete form release agents include chemically active fatty acids, water-based emulsions, and other biodegradable and VOC-compliant products.

### 3.3.6 DRAINAGE CHANNELS AND CULVERTS

Drainage channels and culverts channel water away from or under roads to prevent saturation, flooding, and erosion. In relatively flat areas or where roads follow hillside contours, runoff from the road surface may be allowed to simply drain off the side of the road onto the surrounding land. In other areas, drainage structures need to be included in the road design. Stormwater runoff should flow to the side of the road and should not be allowed to accumulate or concentrate on the road surface nor flow longitudinally along the road surface for a long distance.

Longitudinal drains run along the edges of roads to intercept water flowing toward or off the road and carry the water parallel to the road until it can be diverted. Lateral drains, also known as miter drains, turnout drains, or turnout ditches, carry water from the longitudinal drains away from the road to discharge points. Culverts carry water beneath the road to prevent ponding of water on the upstream side of the road, flooding across the road, and reductions of surface water flow downstream.

The drainage components should be constructed before the roadway is constructed to prevent erosion or flooding from damaging the new road surface. Culverts should be installed across the road before the subbase layer, base layer, and wearing course are placed to prevent disturbance of or damage to the structural layers (Figure 14).

*Figure 14. Double Pipe Culvert*

On short sections of road and sections with gentle slopes or limited runoff areas, grass-lined swales are adequate for longitudinal drains and sometimes for lateral drains. If the flow velocity in a swale may become so great as to cause erosion, the velocity of the water can be reduced by including check dams or riprap within the swale or increasing the number and frequency of lateral drains to reduce the volume and energy in the longitudinal drain.

For areas that are unsuitable for unlined swales, longitudinal drains and lateral drains are frequently open concrete channels or rock-lined channels. Because these channels resist erosion, they can be used on longer slopes and in areas with more runoff. In settled areas, large open channels with periodic high flows pose risks to local inhabitants, especially small children, so adequately spaced safe crossing points may be needed to reduce the risk of people trying to jump or cross the channel during storms. In heavily populated areas, a continuous cover may be warranted.

The water collected in longitudinal and lateral drains eventually needs to be discharged. Because water flows downhill, the discharge point is often into or close to a stream or river or onto a low-lying piece of land unencumbered by structures, such as undeveloped land or farmland. The stormwater runoff in the drains may contain soil particles picked up before the runoff reached the drainage channel or eroded from an unlined channel. To reduce the amount of soil that travels with the collected stormwater, structures such as sediment traps, stilling basins, and detention ponds can be used to slow the water velocity and allow the soil particles to settle out before the stormwater runoff reaches a surface water body or a discharge area that could be degraded by the sediment discharge.

*Figure 15. Gabion Outfall for Drainage Channel Discharge*

The velocity and geometry of the discharge should be controlled so that it does not cause long-term damage, most commonly from erosion. Energy dissipation structures at the discharge point can transform the concentrated, high-velocity flows into slower moving distributed or sheet flows with much lower erosion potential. One common design consists of directing the discharge over and through riprap, where the individual rocks are too large for the discharge water to move them, and the riprap layer is thick enough to prevent erosion of the underlying soil Figure 15. Other designs may consist of a concrete slab on nearly level or gently sloping terrain that fans out like a delta to spread out the flow, with or without integral obstacles on the slab to induce turbulence and reduce the hydrodynamic energy.

In addition to drainage channels, a road project typically includes numerous culverts. Unlike drainage channels used only to collect, direct, and discharge intermittent stormwater, a culvert may pass a permanent or intermittent stream beneath a road. The stream may vary from a trickle in the dry season to a small river during a major precipitation event. The culvert must be designed to handle the maximum design storm event.

Many culverts will be simple pipe culverts smaller than 1 m in diameter. Other culverts may be corrugated metal arches several meters across at their base. Still others may be multi-section box culverts several meters tall and more than 10 m wide, bearing more of a resemblance to a small bridge than to a culvert (Figure 16). Culverts must be large enough to pass debris and sediment so that the culverts do not become blocked.

*Figure 16. Multi-Section Box Culvert*

Culverts should be designed not only for their hydrological capacity, but also to facilitate ecological, habitat, and wildlife connectivity, where appropriate or warranted. In permanent streams, fish may exhibit avoidance behavior near a dark, narrow, enclosed pipe culvert that presents an environment substantially different from the open stream. Designers should consider water depth, water velocity, culvert slope, surface roughness, and the distance between resting pools. Large box culverts or bottomless arch culverts with a natural stream channel substrate may provide a preferred pathway for fish and other aquatic species.

Channel and culvert construction can involve concrete work and often involves lifting heavy components. On smaller culverts, concrete pipe sections rigged with a cable or sling are lifted and placed with a front-end loader or the arm of an excavator. On larger culverts or where access is limited, a crane would be necessary.

Where flows from stormwater runoff are of low quantity and velocity, flows can sometimes be safely carried across the road surface at an engineered dip in the road. The road surface must be able to withstand the erosion forces of the traversing water without erosion and without the road losing structural integrity and rutting beneath wheel loads. This may be an alternative or backup drainage path on low-volume roads that may not receive adequate maintenance or cleaning of culverts.

### 3.3.7 BRIDGES AND WATER CROSSINGS

For large water crossings, the road project may include the construction of a bridge. There are many bridge design and material options, but most bridges are made from timber, steel, or concrete. Bridge construction may involve cast-in-place reinforced concrete, placing precast beams, erecting temporary scaffolding or bridge supports, assembling steel trusses, and other activities (Figure 17). Access may be limited due to the stream or river being crossed. The potential workplace hazards include working at height and drowning. Environmental risks are heightened because all earthwork, concrete work, fuel usage, and other activities take place near, above, or in the waterway.

*Figure 17. Concrete Bridge Under Construction*

Multiple cranes may be needed for bridge construction. If the bridge uses precast concrete girders, the cranes would be relatively large. Crane safety considerations include establishing a firm working base for the crane, which can be more challenging if there is a steep slope down to the stream or river.

For smaller crossings, a pre-engineered truss bridge can be assembled on site without the use of special tools or heavy equipment. At a location where the river course may change due to periodic meandering, bridges built from standardized, prefabricated, portable modular components, such as a Bailey Bridge, can be disassembled and relocated to a new crossing site.

*Figure 18. Bailey Bridge, Saint-Dié-des-Vosges, France*



An alternative to a bridge in areas that rarely experience heavy precipitation could be a low-water crossing, sometimes called an Irish bridge. The simplest low-water crossing creates a hardened, erosion-resistant surface along the road alignment that matches the contours of the streambed. The crossing may consist of gravel, flat stones, concrete pavers, or a complete concrete roadway over which the water can flow without causing damage. During dry or low water conditions, vehicles simply drive across the stream. For larger streams, a drift can be built. A drift is a crossing built above normal water levels that includes multiple pipe culverts to pass normal flows. During flood conditions, water flows over the drift. If the water is too deep or the flow rate is too high, drivers would need to wait for the water levels to recede before crossing so low-water crossings are best suited for low-volume roads.

### 3.3.8 SUBBASE AND BASE LAYERS

The road itself is built up in layers. Excavation may be needed to remove weak or otherwise unsuitable soils. Once foundation soil of suitable bearing capacity is reached, structural fill may be needed to raise the ground level.

When the subgrade soils are at the design level, the structural layer or layers of the road are placed. Although very simple roads may only include a wearing course on the subgrade or structural fill, most roads will include a base layer and possibly one or more subbase layers. The base layer is typically crushed stone, gravel, or a gravel mix, but may be made from weaker soils stabilized with lime, cement, or bitumen. The subbase layer (Figure 19) is normally natural gravel or a gravel/sand mix (Keller and Sherar 2003).

The construction activities and equipment are similar to the those involved in the placement of structural fill. If a stabilizing agent is used, then the handling and mixing of the stabilizer must be considered, including any related waste management.

*Figure 19. Compaction of Subbase Layer*

### 3.3.9 WEARING COURSE

The wearing course of low-volume roads can be as simple as compacted in situ or other locally available soil. In Africa, a reddish-brown lateritic soil, known as murram, is commonly used on unpaved roads. Although many soils may be suitable for unpaved roads in dry weather, soils with a high clay content can become slippery and unpassable when wet. Roads with a wearing course of a compacted gravel and soil mix, a layer of gravel, aggregate with a bitumen binder, asphalt concrete, or Portland cement concrete are better suited for all-weather use. Portland cement concrete roads are not common on USAID-funded projects. Roads also may have wearing courses consisting of flat stones, concrete pavers, or cobblestones or incorporate innovative materials, such as porous concrete or permeable pavement that reduces runoff or “green” concrete that has a lower carbon footprint.

Wearing courses comprised of just soil or gravel are placed in the same manner as a base layer (i.e., placed, graded, and compacted). Construction methods for bearing courses that include binding agents, such as bitumen, cement, or lime, are more complicated because of the need to apply the binding agent or mix it with the aggregate. There are several types of bituminous treatments used to produce an improved pavement, which differ primarily by whether the liquid bitumen or a bituminous emulsion is applied before the aggregate, after the aggregate, or mixed together with the aggregate before placement. The variations may be referred to as macadam, chip seal, fog seal, asphalt, blacktop, tarmac, asphalt concrete, or asphalt pavement; however, the potential environmental impacts of the bitumen are similar.

The construction activities and equipment may be similar to those involved in the placement of structural fill, but also may include specialized equipment for mixing or placing the material used in the wearing course, such as disc harrows for mixing cement or lime into the soil; sprayers for applying bitumen cutbacks (diluted bitumen) or emulsions; asphalt pavers for placement of asphalt concrete; or formwork, concrete mixing equipment, and concrete trucks or pumps to place Portland cement concrete.

#### 3.3.10 BITUMEN

Bitumen, also known as liquid asphalt, is the most common aggregate binder used in road construction.[8] A soft solid at ambient temperatures, bitumen normally needs to be heated before use to reduce its viscosity. If the road project is not near a commercial asphalt plant from which trucks can deliver hot bitumen directly, the road project must supply, store, heat, manage, and potentially mix the bitumen on site. Handling liquid bitumen entails risks of fires, skin burns, inhalation of hydrocarbon fumes, spills, and leaks.

Bitumen is often shipped in 208-liter (55-gallon) drums. The handling and stacking of hundreds or thousands of bitumen drums (Figure 20) often leads to drum dents, punctures, and leaks. The drums must be processed in a bitumen drum decanter that heats the drums and melts the bitumen to drain the drums. Disposal of the empty but bitumen-coated drums can be problematic because steel recyclers may not be willing or able to handle the residual bitumen in the drums.

*Figure 20. Bitumen Drum Stockpile Area*

[8] Although alternative vegetable oil, lignin-based, and plastic aggregate binders have been proposed or tested, they are still experimental (Jenks, 2021) and are not apt to be used on USAID road projects.

An alternative to drums is the use of bulk bitumen containers designed to work with direct heat, hot oil, or electric heating systems (Figure 21). The containers are transported to the site full of bitumen, the bitumen is heated within the container, and the empty containers are then returned for reuse.

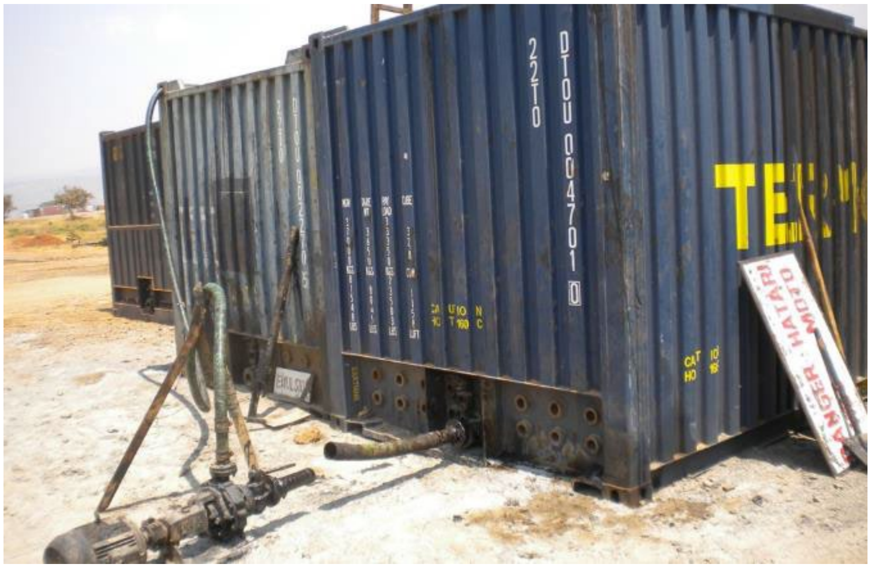

*Figure 21. Heated Containers for Bulk Bitumen*

Bitumen is often diluted or "cut back" with petroleum-based solvents, such as gasoline, paraffin, naphtha, or kerosene. The solvents have much greater potential for soil or water contamination because their lower viscosity increases the risk of contamination from spills and leaks. They also pose a greater fire risk because of their lower flash point. Some solvents may contain hazardous components, such as creosote.

All sites for the storage or handling of bitumen should have secondary containment to contain leaks and spills (Figure 22). Because bitumen is not very mobile, polyethylene sheeting covered by a sand layer may be sufficient. Bitumen solvent storage areas require more stringent engineering controls.


*Figure 22. Leaking Bitumen Drum Storage with Secondary Containment*

### 3.3.11 CURBS

Curbs may be precast concrete, cut stone, or asphalt. Individual precast concrete or stone curb sections can be placed by hand or by using small equipment. Curbing can also be placed continuously by extruding asphalt or slipforming concrete with specialized equipment.

### 3.3.12 WALKWAYS AND CROSSINGS

Pedestrian walkways along the sides of the road provide an important public safety benefit by separating pedestrians from moving vehicles. The walkways may be unimproved or compacted soil or gravel or may be improved with asphalt, concrete, or pavers of brick or stone.

Pedestrian walkways are important not only in heavily populated areas and near schools, but also where the road would otherwise narrow, such as across a bridge, along an embankment, or through a deep cut.

Temporary walkways and crossings may be needed during construction. Residents and business owners must have safe access to their homes and businesses throughout the construction period. Whenever the road project passes through a populated area, pedestrians must be able to safely cross from one side to the other without extensive detours or delays. Safe crossings could require multiple well-signed and monitored pedestrian crossings that should be integrated into the construction traffic management plan. In Figure 23, temporary spoil piles have been placed close to and block access to homes.

*Figure 23. Temporary Spoil Piles Blocking Access to Homes*

During construction, temporary provisions also may be needed to allow herds of domesticated animals, such as cows, sheep, or goats, to cross the road to reach food, water, or shelter.

Because the road itself and any physical barriers or fencing can impede the movement of animals across the road, the road design also may include permanent features to allow or promote animal crossings. Domestic animal crossings may be as simple as well-signed approaches to road sections with long sight lines that facilitate livestock herders moving their animals safely across the road. Wildlife animal crossings may be more complex because of the many types of avoidance behaviors that different animals may exhibit in response to the road materials, noises, and lights. Wildlife animal crossings could include grade separations under or over a road, unlit road sections at potential crossing areas, or fencing that directs animals to preferred crossing points. Wildlife crossings at grade are commonly marked by highway striping or other pavement painting to alert drivers and may incorporate traffic-calming devices to reduce vehicle speeds. Driver warning systems, such as rumble strips or flashing lights, should be assessed to determine whether the noise or lights will adversely affect wildlife behavior.

### 3.3.13 ROAD MARKINGS

On bituminous and concrete roads, road markings are normally painted directly on the roadway. Lane lines also can be applied as thermoplastic tape. Bituminous or concrete roads may have embedded reflectors.

The paint storage area should have engineering controls to contain any spills or leaks.

### 3.3.14 ROAD FURNITURE

The term "road furniture" applies to signs, lights, guardrails, and any other manufactured components typically installed along a road for safety or as navigation aids.

Road signs may be purchased from commercial vendors or may be made by local craftsmen or by the contractor. If the road signs are made on-site, the paint storage area should have secondary containment.

Installation of signage and lights is straightforward and has minimal environmental impacts, except that lighting is a barrier for some nocturnal animals and an attractant for others (Huijser, et al. 2021). Metal posts for guardrails are often hammered into place with specialized equipment that generates some temporary hammering noise. The guardrail post hammering process moves fairly quickly so the noise impacts at any one location are of short duration.

### 3.3.15 LANDSCAPING

A road project will often include one or more forms of landscaping along the road. The most common is the establishment of ground cover to protect against erosion. In areas with a long growing season and adequate rainfall, ground cover can often be established simply by spreading the topsoil that was conserved earlier in the project. In areas with seasonal rainfall, better results may be obtained by spreading the topsoil near the beginning of the rainy season. If intense precipitation is likely before vegetation can be established, the topsoil may need temporary erosion protection.

If growing conditions are not favorable, additional seeding or irrigation may be necessary. Hydroseeding is often used on large projects. Hydroseeding involves the spray application of a mixture of seed, mulch, fertilizer, and other moisture retention materials to establish ground cover, usually grass, on bare or partially vegetated areas. The hydroseed mix includes a tackifier that helps bind the components together and to the soil surface while providing some erosion protection. Hydroseeding mix is commonly dyed green to visually aid in the application and for aesthetics.

Vegetation also may include shrubs or trees to provide habitat, add visual appeal, limit visual or noise impacts, or replace removed vegetation. The vegetation selected should only include native plant species. Landscaping crews should be trained to identify non-native, invasive, or undesirable species so that they can be removed and destroyed.

### 3.3.16 WASTE MANAGEMENT

Road projects generate a substantial variety and amount of waste. The waste types can include removed vegetation; unsuitable soils; waste rock; demolition debris from removed structures; waste building materials from camp construction; concrete rubble; waste (unused) concrete; concrete wash water; packing materials from office, workshop, or camp supplies; food waste; sanitation waste; household waste; waste oils and greases; used solvents and cleaning fluids; oil filters; oily rags; damaged or worn-out equipment parts; old tires; empty hazardous material containers; contaminated soils or absorbent spill materials from spills, leaks, or cleanup responses; empty bitumen drums; and temporarily used materials for signs, fencing, concrete forms, and workshop tables or shelving.

The wastes fall into several broad categories:

- **Plastic** constitutes a significant component of household and office waste, primarily from water bottles, food packaging, and materials packaging. The plastic should be collected separately and recycled, especially if engineered landfill options are not available. Recycling the plastic may involve transporting it to a major urban center.
- **Paper and cardboard** could be recycled but because it is biodegradable, it may be acceptable to dispose of it in a local landfill, even if the landfill is not properly engineered. Disposal in an open dump is less satisfactory because the paper is apt to be scattered by the wind. Paper and cardboard can also be burned on-site, preferably in an incinerator with a controlled draft. Paper and cardboard can also be buried on-site if drainage and groundwater conditions are satisfactory.

- **Glass** can be collected separately and recycled like plastics, but because it is inert, it also can be disposed of in a local landfill, even if the landfill is not properly engineered.
- **Food waste**, in some areas, can be buried on-site where it will safely decompose. The waste should be routinely buried beneath a layer of cover soil to isolate it from vermin and to reduce odors.
- **Metals**, including scrap rebar, wire, machine or equipment parts, structural members, building materials, and old road signs, can be recycled as scrap, often at a profit.
- **Other non-hazardous solid waste** can be disposed of in a local landfill. If a properly engineered landfill is not available, the environmental impacts of the available options should be weighed against the costs and impacts of transportation to a better disposal site.
- **Waste oils and other hydrocarbons**, such as hydraulic fluids and greases, can often be recycled because they can be reprocessed and resold. If there is a refinery in the country, there will often be companies that consolidate collected oil from small shops and transport it in bulk to the refinery. If there are no refineries in the country, there may be stand-alone oil recyclers who operate oil recovery equipment. An oil recycler will typically also manage waste oil filters.
- **Special wastes**, including certain wastes such as used tires and empty bitumen drums (Figure 24), may require finding a local or in-country business that has the capabilities to manage these wastes properly. The technical capabilities and the business practices of the business should be carefully assessed to verify that the wastes will be properly handled. If the business is required to have permits to handle these wastes, the permits should be reviewed and verified. The waste materials may need to be transported to a major urban or industrial center to be handled properly.
- **Hazardous wastes** should be handled by a licensed hazardous waste hauler and a licensed treatment or disposal company. All parties should be fully vetted by the project's environmental staff. All hazardous waste should be shipped with chain-of-custody documents and shipping manifests. Confirmation documentation of proper treatment or disposal should be returned to the project and maintained in the project files.

*Figure 24. Empty Bitumen Drums Awaiting Offsite Disposal*

The contractor should develop a waste management plan that estimates the types and quantities of all potential wastes in the waste stream, from mobilization through decommissioning. The plan should detail the disposal method, means of transportation, location, and parties responsible for each component of the waste stream. All waste shipments should have a manifest system to confirm delivery and to document the waste quantities.

If any wastes are buried on-site, the types, volumes, locations, and global positioning system (GPS) coordinates of the buried wastes should be recorded. The burial locations should be marked on the project plans and delineated in the field, perhaps by stone boundary markers. Warning signs or buried warning tape should mark the site to prevent inadvertent exposure of or to the waste. If animals are likely to dig up the waste, especially food waste, a surface or buried layer of gravel or cobbles can inhibit digging.

## 3.4 DEMOBILIZATION

When construction in an area is substantially complete, the contractor will demobilize unneeded equipment and materials, remove temporary infrastructure, discharge or relocate workers, and clean up and restore the site. Demobilization and site reclamation processes are an integral part of the construction process and should be completed before the project is accepted by the owner.

Demobilization plans are often developed in advance to ensure that planning and logistical operations are well coordinated. To confirm that all necessary environmental and social provisions have been duly met and that the appropriate controls and requirements were implemented, owners often develop a checklist or punch list that includes all relevant work items that need to be completed and verified before project handover and final project payment.

Demobilization of all site areas does not and generally should not only occur after the rest of the construction is completed. Rather, demobilization and restoration of areas should occur as early as possible in the construction schedule, consistent with the contractor's needs. On a road project, demobilization of one site may involve moving equipment to a new site further down the road, closer to the current working front.

### 3.4.1 CLOSURE AND RESTORATION OF DETOURS AND TEMPORARY ROADS

Temporary traffic detours, access routes, contractor haul roads, and vehicle and equipment parking areas developed for the road project should be removed and the land reinstated to its preconstruction condition or to another environmentally acceptable condition agreed upon with the landowner.

Generally, restoration involves removing any surface improvement, such as gravel, geotextiles, or temporary pavement and then ripping the upper 0.30 m to 0.50 m to loosen the soil, remove the effects of compaction, increase aeration, and promote water infiltration and moisture retention. The land is typically revegetated with species consistent with its preconstruction condition and adjacent areas. Revegetation may be used to upgrade the land by replacing pre-construction invasive species with native species or by planting species that provide better habitat for area fauna.

In some cases, local communities may prefer to retain the benefits of a road developed for construction. Ideally, the decision to restore or retain a road developed for construction access should be made during the planning and design phase so that the details, impacts, and sustainability of the road's final condition are properly assessed.

### 3.4.2 REMOVAL AND RESTORATION OF FIELD OFFICES, CAMPS, WORKSHOPS, AND LAYDOWN AREAS

All project sites occupied or used by the contractor must be restored to a condition suitable for their future intended uses and as agreed to with the landowners or responsible government agencies. During demobilization of areas used for field offices, construction camps, workshops, and laydown areas, all contractor equipment, contractor materials, and construction-related debris and waste materials must be removed.

The removal of temporary infrastructure includes the removal of utilities and buildings, such as housing, offices, warehouses, and workshops. Usable buildings and construction infrastructure may be turned over for public use or potentially sold to private owners; however, the buildings and land transferred must be in an environmentally acceptable condition. Ideally, the decision to remove or transfer project infrastructure should be made during the planning and design phase so that the details, impacts, and sustainability of the infrastructure are properly assessed.

Removal of buildings and other major temporary structures includes the demolition and removal of the foundations to at least a predetermined minimum depth below the ground surface. Temporary underground utilities are normally shallow and should be removed entirely. Any temporary road furniture, such as signage or barriers for detours, also should be removed.

Stormwater management features may need to be modified or built to accommodate the restored property grading and drainage needs once work areas have been demobilized. Modifications may include removal or filling stormwater basins, creating or modifying vegetated infiltration basins, removing or adding culverts, or installing additional new drainage features and soil erosion protection.

#### 3.4.3 REMOVAL AND RESTORATION OF FUEL STORAGE AREAS

The removal of fuel storage facilities is similar to the removal of other site infrastructure, but with additional steps required for the removal of any remaining fuel and additional attention needed to prevent, identify, and remediate any fuel leaks and spills.

Initial steps include consuming or extracting any fuel from the tanks to be removed. Fuel use should be planned so that minimum quantities of fuel are left at demobilization. Any remaining fuel is either used in equipment and vehicles or is transferred to portable tanks.

The removal of fuel storage tanks, whether underground or aboveground, should be done according to the tank manufacturer's instructions and any applicable code requirements. Tank removal includes draining and removing any associated piping and pumps and demolishing and removing the tank's aboveground support structure or underground vault, the secondary containment structure, and any concrete slabs in the fuel dispensing area. The disposition of the removed materials may depend on the existence and extent of any fuel or oil contamination. Clean materials should be segregated from materials contaminated with hydrocarbons to minimize the amount of potentially hazardous waste.

The fuel storage and fuel dispensing areas should be carefully examined for the presence of soil contaminated by leaks or spills. If fuel leaks or soil contamination are identified during the decommissioning of fuel storage areas, then a soil sampling plan should be prepared to establish the limits of the contamination and a remediation plan should be developed for the removal and disposition or treatment of the contaminated soil.

#### 3.4.4 CLOSURE AND RESTORATION OF BORROW PITS

A site restoration plan for each borrow pit should have been developed as part of the use agreement with the landowner. The agreement typically describes the conditions for closure, but the detailed closure design and restoration plan are defined after the final limits of the excavation are known.

Borrow pit restoration plans generally include grading the final topography to conform to the surrounding landscape, providing free drainage from the borrow pit area, eliminating any steep drop-offs or unstable slopes, restoring topsoil, revegetating the area, and restoring any temporary haul roads. The closure plan should consider surface water runoff and incorporate any drainage channels, culverts, or detention basins needed to prevent soil erosion. Occasionally, the landowner might want the final geometry to capture and retain water for irrigation or livestock use. Best practice is for the landowner and contractor to agree on the closure details and to have the landowner sign a final release indicating that the conditions were met to the landowner's satisfaction.

During operation, borrow pit excavation should be planned with subsequent closure in mind. In particular, if deep pits need to be backfilled, the source and amount of material required for the backfilling should be planned. Because it is more economical than hauling material to the borrow pit site for restoration, the geometry and volumes of excavation should be planned to maximize the use of on-site materials to establish post-construction topography. Potential on-site fill materials include soil in overburden stockpiles and in perimeter water-diversion berms. If additional fill material is needed, excess soil and rock from unbalanced cuts, excavated soils that are unsuitable for construction, or—with the consent of the landowner—concrete rubble or other inert materials can be used.

Topsoil that was removed and segregated when the borrow pit was opened should be spread over the surface after the final profile has been achieved. The site should be seeded or revegetated in a manner suitable for its intended future use and in accordance with the landowner agreement. Grass is commonly established using hydroseeding, which involves spraying a mixture of seeds, water, nutrients, a water retention material, and a tackifier from a tank truck. The hydroseeding mixture provides a temporary, protective, erosion-resistant layer that provides favorable conditions for seed germination. Revegetation should only use suitable native plant species and prohibit the introduction of invasive species.

If the future use of the land is for agriculture, the final condition of the land should be defined in the landowner agreement. If the post-project land use is to be different from the pre-project land use, the impacts of the land conversion should be included in the road project's environmental assessment.

A road project will often have multiple borrow pits along the length of the project to minimize haul distances. As soon as the contractor is reasonably sure that a borrow pit is no longer needed, restoration can begin. Large borrow pits can be closed in phases. Borrow pits should be closed and restored as early as possible in the construction cycle and not delayed until the project is nearly completed. Prompt closure and restoration minimizes the potential for erosion, provides time for the contractor to establish vegetative cover, and minimizes other environmental and social risks. From a practical standpoint, near the end of a project, contractors are often eager to move equipment and personnel to other projects and may not devote adequate resources to restoration activities.

### 3.4.5 CLOSURE AND RESTORATION OF QUARRIES

The closure and restoration process for quarries is conceptually similar to the process for borrow pits but has some significant differences because of the material type and the scale of quarry operations. As with borrow pits, quarry closure generally involves providing free drainage from the quarry area and minimizing any steep drop-offs or unstable slopes. However, whereas a road project may have many borrow pits, it will usually have only one or a few quarries because of more specific material requirements, the larger fixed plant needed, and the greater set-up time required.

Quarry operations are often larger than borrow pit operations. Because hard rock excavation is substantially more difficult than soil excavation, the final topography is less likely to conform to the surrounding landscape unless the quarry management plan specifically planned the rock extraction to achieve that objective. Similarly, depending on the specific geometries that were blasted or excavated to exploit the required rock, it may not be feasible to eliminate all steep drop-offs or unstable slopes. Finally, the barren rock surface is not always covered with topsoil or revegetated.

The quarry closure and restoration specifications will be determined by the features of the site, including the nature of the rock extracted, the quarry size, quarry location, and the nature of potential hazards. The surface contours and watershed collection areas are assessed to determine the drainage pattern, potential for ponding, and requirements for stormwater runoff management. Quarry areas may then be subjected to a shaping exercise to modify the site profiles; however, this should not be expected to eliminate all physical hazards on the site.

If overburden soil was removed to expose the rock resource, the stockpiled soil can be reused to improve the final site contours. Similarly, stockpiled topsoil can be spread and revegetated if the final contours allow.

Several potential post-closure environmental and public safety threats from quarries may remain even after closure unless carefully planned rehabilitation is undertaken. For example, the exposure of some rocks to oxygen and moisture can produce acidic conditions that mobilize heavy metals in stormwater runoff or leachate from waste rock piles. The migrating pollutants can pose human health and ecological threats in surface waters. Water pooled at former quarry sites also can become a source of vector-borne diseases or present a drowning risk.

Quarry closure can be complicated by the desire of local authorities or communities to keep a former quarry in its end-of-construction state despite potential risks. Once a quarry is developed, it can be a valuable resource for future rock extraction for other construction projects or future maintenance of the road. As such, regrading and backfilling all or parts of the quarry to reduce physical hazards may be in conflict with retaining the quarry in the optimum condition for future use. In water-scarce areas, a quarry that retains water may be seen as a valuable water source for watering livestock, irrigating crops, or other uses. Where such conditions are left in place at the end of construction, the agreements with the landowner or authorities should clearly address the party or parties responsible for potential future liabilities.

Rehabilitated quarries (or large borrow pits) have occasionally been repurposed for public uses. The typical concave geometries and side slopes lend themselves to spectator seating for sport, theatrical, or concert facilities. If the site can be transferred to a community group or local government that wishes to develop it as a local amenity, the quarry development and closure plans should involve close coordination with the future owner to address issues related to the final closure conditions and post-closure liabilities.

## 3.5 ROAD REHABILITATION

Over time, roads deteriorate for a variety of reasons, including long-term traffic wear, heavy vehicle loads, erosion, moisture or temperature extremes, inadequate design, poor construction, or inadequate maintenance. Periodically, the effects of deterioration need to be reversed by adding or replacing material in the existing road structure. Rehabilitation is the act of repairing portions of an existing road to counteract the deterioration process and extend the service life of the road.

Road rehabilitation projects restore the structural integrity of the existing roadway on the same alignment, with possible minor deviations. The nature and extent of road rehabilitation projects depend on local conditions and the types of road distress. They are generally less intensive than new road construction, require fewer materials, and involve little to no land use change or vegetation removal. Road rehabilitation projects are more intensive than routine maintenance and may involve removal of the road or parts of the road from service for an extended period of time.

### 3.5.1 REHABILITATION OF UNPAVED ROADS

At certain intervals, virtually every soil and gravel road will require some form of rehabilitation beyond routine maintenance regrading. Rehabilitation may be needed due to severe and persistent rutting; loss of road crown;[9] or the formation of berms from the shifting of material from travel lanes to shoulder areas due to displacement by vehicle tire stresses, winter plowing operations, erosion during heavy rains, or poor routine regrading practices.

Rehabilitation work performed on an earthen road generally involves removing the wearing course and base layer materials, adding or removing subbase materials to restore or obtain the desired geometry, replacing and recompacting the base layer, and reconstructing any wearing course.

The material needs for rehabilitating a road are significantly less than those required for a new road because the rehabilitated road geometry—width, length, grade, and crown—will be substantially the same as before. Exceptions may include where the road geometry needs to be modified to overcome evident deficiencies, such as severe rutting due to water ponding or high groundwater, erosion along or across a road, unsafe curves, or difficult ascents. Most or all of the materials needed for base layer compaction would be from the removed materials or from balancing any cut and fill. If the road wearing surface was gravel, additional new gravel will probably be required to restore the design thickness due to gravel displaced to the shoulders or embedded in the base layer. The provision of gravel or additional soil materials may require sourcing materials from a borrow pit or quarry.

[9] "Crown" describes the height variation of the profile across a road. Unpaved roads often have a more aggressive crown than paved roads so that surface water drains off more quickly. A related term, "camber," refers to the transverse slope of the road surface.

Road rehabilitation also may include restoring or upgrading drainage channels along or culverts crossing the road, especially if the operational or maintenance experience identifies drainage deficiencies. This may involve returning drainage ditches to their original profile or modifying their geometry to better accommodate stormwater flows. Disturbed surfaces in grass-lined swales or in other vegetated areas should have their ground cover restored as promptly as practical to minimize the potential for soil erosion. Rehabilitation of culverts could include replacing culverts, enlarging culverts, or adding culverts.

Road rehabilitation typically involves equipment similar to that required for road construction (e.g., graders, front-end loaders, compaction equipment) but generally requires a smaller quantity, smaller-sized equipment, and fewer trucks. In some locations where labor is plentiful and inexpensive, road rehabilitation projects may be undertaken primarily with manual labor.

### 3.5.2 REHABILITATION OF PAVED ROADS

Rehabilitation of paved roads can include everything involved in the rehabilitation of unpaved roads plus repair or replacement of the bituminous or cementitious wearing course. If the conditions of the structural base and subbase layers are satisfactory, a pavement overlay may be sufficient to seal, stabilize, and restore the serviceability of the road. Overlays are appropriate in areas of pavement wear or areas where pavement failure is not caused by an underlying base or subgrade problem. Minor rutting, raveling, pitting, minor cracking, and asphalt oxidation are typical failures where an overlay can be effective in quickly restoring the surface. Pothole patching, crack repair, or milling treatments of the existing surface work may be necessary before a new overlay can be applied.

There are a number of techniques for rehabilitation of asphalt or concrete pavement. For asphalt, a new hot-mix asphalt layer can be laid over the existing road surface or the existing asphalt layer can be removed and recycled offsite or processed in place through hot in-place recycling, cold in-place recycling, or full-depth reclamation. Portland cement concrete pavements can be rubblized in place to create a base layer, which is then overlaid with asphalt concrete. Recycling worn-out asphalt or concrete pavements in place saves material, transportation, and handling costs; reduces construction time; and has less impact on the environment. Several of the in-place recycling options also require a new hot-mix asphalt or other overlay for the wearing course.

Pavement rehabilitation, as with pavement construction, requires a series or "paving train" of equipment, which may include—depending on the process—a milling machine, reclaimer, crusher, screener, pugmill mixer, paver, and roller compactors.

## 3.6 OPERATION AND MAINTENANCE

Operation and maintenance comprise the routine functions required for satisfactory road performance. Operation includes functions such as training, management, budgeting, and general organizational practices, whereas maintenance deals with the physical upkeep and minor repairs of the road.

Maintenance aims to keep the road system as close as practicable to its constructed condition and service level. Road maintenance works can generally be classified as routine, periodic, or emergency. Routine maintenance is based on frequent inspection of the road surface, adjacent slopes, drainage structures and conditions, bridges, and other components to identify any defects or damage. Periodic maintenance is performed at predetermined time intervals, such as seasonally or yearly, depending on the components involved. Finally, emergency maintenance generally involves work to restore road and road-related facilities to their normal operating conditions after they are damaged by accidents or natural causes.

Typical interventions include pavement maintenance and preservation, cleaning drainage structures, mowing and management of roadside vegetation, rockfall and landslide cleanup and hazard reduction, removal of accident debris and litter, removal of roadkill, guardrail and fence repair, sign repair and replacement, repair and maintenance of streetlights and traffic lights, snow removal and deicing, and sidewalk and bicycle lane maintenance.

### 3.6.1 SURFACE MAINTENANCE OF UNPAVED ROADS

Routine maintenance on earthen roads generally involves light grading to keep the road smooth; removing slight defects such as ruts or ridges; and ensuring that water cannot pond any place within the cross section, including the side ditches. Typical defects include loss of crown, a corrugated or washboard surface, ruts, ridges, potholes, and loose or missing aggregate.

Maintaining the proper cross-sectional profile is important so that water drains efficiently off the crowned travel surface, across a sloped shoulder area, and into a side drainage ditch or other feature to move water away from the road. On gravel roads, the gravel layer may need periodic replenishment because traffic tends to thin the gravel layer by displacing gravel from the travel surface to the shoulder or drainage ditch. Segregation of soil particles also can cause an accumulation of fine soil, which can contribute to dust generation. The loose, fine soil may require periodic removal.

Occasional recompaction of the road surface helps to maintain a tight, dense surface that absorbs less water, promotes water runoff, and generates less dust. Dust can be reduced through the application of water; however, that only provides a short-term solution and is best suited for spot treatment when dust may present a particular nuisance, such as near a temporary market or festival. Stabilizing agents (e.g., calcium chloride or magnesium chloride) offer a longer-term solution to minimize dust emissions on unpaved roads.

The primary pieces of equipment needed to maintain unpaved roads are the motor grader and roller compactor. However, material can be redistributed and shaped on the road surface using front-end loaders or farming equipment, such as disk harrows and landscape rakes. Satisfactory compaction can be achieved with heavy trucks. In remote areas, road maintenance can be accomplished with draught animals or manual labor.

### 3.6.2 SURFACE MAINTENANCE OF PAVED ROADS

Surface maintenance of paved roads helps slow the deterioration of the pavement layer and defer more costly repairs. Common pavement maintenance includes crack and surface sealing, surface leveling, patch repairs, pothole repairs, and curb replacement.

Surface sealing (e.g., fog sealing, slurry sealing, or chip sealing) using asphalt sealing products restores flexibility of the pavement, protects against the effects of sun and water, increases skid resistance, and fills small cracks and other surface defects. Asphalt concrete leveling consists of the placement and compaction of plant-mix asphalt concrete over ruts, distortions, depressions, and other irregularities to restore proper grade and cross section to the existing pavement.

Pothole repair typically includes removing loose material and replacement and compaction of new material, either as a partial- or full-depth repair. Patch repairs of short pavement lengths or limited-width repairs can be completed by overlaying the surface with new hot-mix asphalt, either with or without prior milling of the existing road surface.

Conventional asphalt pavement is flexible and can deform over time by the force and heat generated by large vehicles, such as braking buses. For rutted bus stop pavements, the repair procedure is usually to remove the deformed asphalt and replace it with a high-stability asphalt mix. Portland cement concrete pads, which are harder than asphalt concrete, are sometimes strategically installed at bus stops to prevent this type of pavement distress.

### 3.6.3 DRAINAGE SYSTEMS

Poorly maintained drainage systems can contribute to erosion of the roadway, saturation of the subbase, and damage to roadway structures. Functioning drainage systems are critical for preventing flooding and washouts.

> *In Haiti, catch basins along a newly commissioned road became clogged with garbage and silt shortly after the road was commissioned, blocking the subsurface storm drainage system.*
>
> *Inadequate maintenance of the catch basins resulted in frequent standing water and flooding, which caused the road to fail.*

Regular drainage upkeep includes maintaining positive drainage from the roadway surface to the shoulders and drainage components without ponding. To maintain proper flow of water away from the road, periodic cleaning and repair of drainage swales, ditches, channels, inlet structures, and culverts are needed.

Cleaning ditches and open channels is one of the most important tasks for maintaining good drainage along any type of road. Open drainage systems tend to collect garbage and debris, which must be regularly removed to prevent blockages. Both earthen and lined ditches require maintenance to prevent erosion that can create roadside hazards and/or reduce the effectiveness of the drainage system. While some vegetation in roadside ditches can reduce erosion, a well-maintained, smooth-flowing ditch will be free of heavy vegetation (e.g., tall grass, trees, cattails).

Curb and gutter units that collect runoff water from the pavement and direct it to inlets require regular clearing of debris and silt so that water can run freely. Storm sewer lines with flatter slopes may need periodic cleaning or flushing.

On older roads, on roads for which climate change may not have been adequately addressed during the initial design, or on roads that have otherwise experienced hydrological conditions that exceed the original design assumptions, it may be necessary to upgrade portions of the stormwater management system to accommodate higher flows. The need for upgrades to culverts or other drainage structures should be evaluated as part of periodic road maintenance and repair.

### 3.6.4 VEGETATION

Management of vegetation along the road verges and in medians represents the most common roadside maintenance task. Vegetation management is important for preventing erosion, preserving the integrity of the traveled way, and protecting motorist safety. Grasses should be limited to a height that does not impair driver visibility, either by careful species selection or by periodic mowing. Uncontrolled growth of trees and woody brush should not be allowed where such growth presents a safety hazard. Trimming and removing excess woody vegetation increases sight distances for drivers, reduces the buildup of snow drifts, removes potential hiding places for large animals near the roadway, removes collision hazards for vehicles veering off the road, and reduces the need for cleanup of vegetation following storms. On low-volume unpaved roads, maintenance may include removal of vegetation growing along the edges or between wheel tracks of the earthen travel lane itself. The maintenance program may include periodic surveys to identify any noxious or invasive species and subsequent control measures.

Grasses are typically managed by periodic mowing with mechanical equipment designed and suited for the vegetation and terrain. Infestations of invasive plant species may need to be managed through an integrated program. Any use of herbicides must follow health and safety procedures to protect people and the environment, must be used according to manufacturer's specifications, and may require preparation of and compliance with an approved PERSUAP.

### 3.6.5 WINTER OPERATIONS

In cold climates, road maintenance activities include snow removal, deicing, and application of materials to improve traction. Snow is typically plowed from the travel lanes and pushed to the sides of the road. The accumulated snow forms snowbanks, which can reduce sight lines and conceal animals, such as deer, which may bolt across the road.

Deicing materials are typically sodium or chloride salts applied in granular form or in solution. Salts are an effective tool for deicing but can accelerate deterioration of some road components, such as steel in concrete reinforcement or bridges. Runoff from precipitation or snow melt can transport deicing salt to surface waters, impairing water quality.

Traction on icy or snow-covered roads can be improved by spreading a thin layer of sand or other angular aggregate, sometimes mixed with a deicing salt. The sand may accumulate throughout the winter and require removal in the spring from the road and from drainage structures.

### 3.7 DECOMMISSIONING

Roads that are no longer used or needed may be decommissioned and removed from the transportation inventory. Also, if a road is realigned during a road improvement project, the abandoned road segments may be decommissioned. Roads are often taken out of service by simply physically blocking off a section of road using gates, berms, boulders, logs, or other barriers to restrict vehicle access. Over time—often several decades—the pavement (if present) deteriorates due to weathering and vegetation re-establishes itself in the roadway.

True decommissioning of a road, however, means removal of any pavement, drainage structures, road signs, guardrails, and other road furniture. The removed materials must then be reused, recycled, or properly disposed of. The upper 0.30 m to 0.50 m of soil should be loosened to remove the effects of soil compaction, increase aeration, and promote water infiltration and moisture retention.

Because closed roads are rarely inspected, it is important to leave them in a condition that is not susceptible to erosion. The land contours may need to be modified to conform to the surrounding landscape, remove drainage channels, and promote natural drainage without erosive flows. Regrading may be necessary to prevent water from following the course of the abandoned roadway, e.g., by increasing the transverse slope of the road or adding small berms of drainage swales across the roadway.

The decommissioned areas should be revegetated with suitable native plant species consistent with adjacent areas. Narrow tracks often will revegetate naturally with no noticeable scars or impact on the environment. Wider roads may require active planting and reseeding. Habitat continuity should be restored (Goosem, Izumi and Turton 2001) through road restoration projects by the restoring the habitat that was degraded by the road and reestablishing the connection across it. In sensitive areas, ongoing monitoring and evaluation may be needed until the restored habitat is self-sustaining.

If periodic inspection indicates encroachment by motorized vehicles, additional barriers or other measures may be needed to limit use, especially if the road was decommissioned to prevent access to a protected or ecologically sensitive area.

# 4 ENVIRONMENTAL AND SOCIAL IMPACTS AND MITIGATION MEASURES – ROAD CONSTRUCTION

In this section, impacts of road construction are categorized as ecological, physical, waste management, human health and safety, and social impacts and are considered separately from the impacts of road operation. Many components of road construction have multiple, cross-cutting impacts. This section can be used to identify significant environmental issues associated with construction of a road project and to develop a construction mitigation and monitoring plan.

Mitigation measures help avoid the need for later remediation of adverse impacts by requiring the implementation of best practices throughout the project life cycle, including during project design, preparation of IEEs, and during the development of EMMPs.

## 4.1 ECOLOGICAL IMPACTS OF ROAD CONSTRUCTION

### 4.1.1 CHANGES IN LAND USE

Many aspects of road construction involve changes in land use. Some of the land use changes may be temporary, small, local, and unconnected, such as at the site of an isolated borrow pit, while others will be permanent, large, extensive, and interconnected, such as those along all areas crossed by the alignment of a new road. Although most sites with land use changes may experience specific impacts related to vegetation disturbance, habitat changes, and direct physical impacts, this section focuses on the overall impacts related to the change in use, such as from a natural setting to developed land or from agricultural use to a transportation corridor.

If the project involves construction of a new road, most of the land area of the road alignment will undergo a land use change. If the project is for a road improvement, the land area of the new road alignment is likely to be greater than the footprint of the original road. These land areas will be converted from their prior uses to part of a transportation corridor.

Changes or restrictions in the right-of-way corridor also may lead to land use changes, such as from agricultural land to open land. If land acquisition was required, some land may transition from residential or commercial uses. If resettlement was required, some land may transition to residential or commercial uses. Areas used as borrow pits, quarries, detours, or camps may transition from natural settings or agricultural uses to a temporary use during road construction and then to a restored natural setting, agricultural land, or other use. On temporarily impacted land, the post-construction land use may differ from the pre-construction land use.

***Management and Mitigation Measures.*** Although any land use change may have specific, local effects, the cumulative land use changes for the entire road project should be determined and quantified. Mapping the land use changes provides a visual representation of the locations, magnitudes, and types of changes and may help identify cumulative impacts that would otherwise go unnoticed.

### 4.1.2 DEFORESTATION AND LOSS OF VEGETATION

Land cleared for the road itself or for camps, workshops, laydown areas, borrow pits, quarries, detours, or any other site required for construction is stripped of its existing vegetation during clearing and grubbing. The loss of forest or other vegetative cover during construction can contribute to increased stormwater runoff, flooding, soil erosion, loss of topsoil, desertification, and degradation of surface water quality. The loss of forests contributes to increased atmospheric $CO_2$ concentrations because forests act as carbon sinks.

Forests are important for sustaining biodiversity and for providing an array of valuable ecosystem services, such as storing carbon, limiting soil erosion, and reducing downstream flooding (Laurance, Clements, et al. 2014). Opening new roads for expanded agricultural development, economic growth, market accessibility, and natural resource extraction puts adjacent forests at risk, especially where no effective forest management systems are in place (Wilkie, et al. 2000). Typically, the most significant impact on forests results from clearing forest land for alternate use. However, once a road is in place, it also provides access to people wanting to supply markets with wood products, such as charcoal, fuelwood, bush meat, or construction materials, contributing further to deforestation, increased carbon emissions, and a loss of carbon sinks (Laurance, Goosem and Laurance 2009). New road development also has been shown to increase wildfire risk (Ricotta, et al. 2018).

Grasslands are globally important and also provide important vegetative cover and feeding grounds for numerous prey and predator species. Land use change caused by roads can either damage native grasslands or cause grassland loss, leading to non-native grasslands (i.e., alien and invasive plant species spread) or changes to the carbon cycle (Williams, McDonnell and Seager 2005).

***Management and Mitigation Measures.*** The strongest mitigation measure possible is to locate roads during the planning and design phase where they do not require deforestation and where removal of high-value, vegetated habitat can be minimized. Vegetation should only be removed when necessary and where necessary for construction operations and, if possible, it should be left in place in areas prone to erosion or mass movement, such as near riverbanks or on slopes.

Cleared areas should be revegetated as soon as practicable. Setting up nurseries in project areas can help supply the requisite volume of native plants for landscaping along the road, restoration of disturbed areas, and revegetation for erosion control. The nurseries also can provide social and economic benefits by providing jobs in local communities. Care should be taken not to introduce invasive plant species when reestablishing vegetation.

Where deforestation or loss of vegetation by roads is unavoidable, compensation measures may be put in place to restore a similar amount of unfragmented habitat. Mitigation for disturbance of rare, threatened, or endangered plants may require their removal and relocation through a variety of transplant techniques. Replacement requirements often stipulate planting a greater amount of the target species than was removed to improve viability and compensate for replacing mature vegetation with younger plants.

### 4.1.3 HABITAT DISTURBANCE, REDUCTION, OR FRAGMENTATION

Despite widespread recognition of roads being a threat to biodiversity, road density continues to increase worldwide (Laurance, Sayer and Cassman 2014), and huge budgets are devoted to the construction and upgrading of roads with little or no allocation to mitigation measures to protect biodiversity (van der Ree, et al. 2011). Road construction therefore poses a threat to the survival of individual animals and animal populations due to habitat loss, fragmentation, and degradation. These direct habitat impacts change the structure of the landscape and therefore indirectly affect the associated ecological processes (Sanz, Serrano and Puig 2001), such as dispersal or migration of terrestrial and aquatic wildlife with the adverse consequences only becoming apparent over time. Impeding animal movement and habitat accessibility by separating an otherwise integrated ecosystem may lead to the unavailability of plant species or terrestrial and aquatic animal species that a community typically uses.

The clearing of forests or grasslands destroys habitat directly, reduces the area of remaining habitat, and can fragment the remaining habitat into multiple, disconnected parcels of lower ecological value. The reduction or degradation of habitat can lead to species decline or loss.

Road construction that leads to habitat destruction can create avenues for the spread of alien and invasive plant species that exploit disturbance opportunities and outcompete the native species, particularly on roadside verges. Widening the cleared areas adjacent to roads may further increase the spread of alien and invasive plant species (Rahlao, et al. 2010).

***Management and Mitigation Measures.*** Although the direct impacts occur during construction, mitigation measures need to be introduced during planning and design. Contiguous habitat should be maintained where feasible during the planning and construction phases to prevent habitat fragmentation, retain buffer zones between roads and sensitive ecosystems, and maintain migration corridors.

When planning the road alignment, an ecosystem service valuation (ESV)[10] can help evaluate the value of habitats, document current ecosystem services, and estimate how different road development scenarios would impact those ecosystem services in the long term. Assessing the value of current and projected ecosystem services allows a holistic view of potential social and environmental impacts. Over a 20- or 30-year period, these impacts, such as decreased agricultural land or increased deforestation, may prove to be cumulative and highly significant. Estimating the impacts of different development scenarios on ecosystem services will help reveal the most harmful effects to be avoided or mitigated. An ESV can help communities realize the trade-offs associated with the development and management of roads and can be used to identify alternatives that minimize and mitigate the most harmful environmental and social impacts. For more information about applying an ecosystem services framework to the Environmental Impact Assessment process, see the Environmental Compliance Factsheet: Ecosystem Services in the Environmental Impact Process (USAID 2018).

Local experts should be consulted regarding restoration to prevent the introduction of non-native species. Construction crews should be trained in the early removal of exotic plant species that have been accidentally (e.g., transported on road machinery) or otherwise introduced and in the preservation of native plants, especially when roads pass near or within protected areas.

#### 4.1.4 OTHER

Other ecological impacts that may result from road construction and associated activities include noise disturbance, physical disturbance, light pollution, and the introduction of pollutants.

*The environmental review for an Asian Development Bank bridge project over the Rioni River in Georgia (country) determined that Stellate Sturgeon, Russian Sturgeon, and Beluga Sturgeon, all of which appear on the IUCN Red List of Threatened Species, were present in the river.*

*Mitigation measures included limiting in-river construction and disturbance to periods outside of the sturgeon spawning season to reduce the potential for displacement and mortality impacts on the three priority sturgeon species.*

Noise disturbance may affect fauna that is dependent on habitat adjacent or proximate to road construction sites. The most common causes of noise disturbance include the operation of earthmoving equipment and construction vehicles; quarry operations (including blasting); the loading, transport, and offloading of construction materials; and transportation of or communication among construction crew members during construction activities.

In addition to the physical disturbance caused by land clearing and changes in land use, incidental physical disturbance can occur from ancillary activities of persons and vehicles. Pedestrian pathways may develop from the movement of construction workers to commercial or recreational areas and new pathways may develop as area inhabitants avoid construction zones. These pathways can damage habitat and disturb sensitive wildlife.

Construction activities taking place during evening hours may require high-powered lighting to enable safer operations. This artificial lighting may affect and disturb nocturnal fauna by affecting their natural navigation functions, exposing prey to predators, or disrupting breeding behaviors and patterns.

Finally, the operation of construction vehicles and machinery, and certain types of road construction itself (e.g., bitumen roads), requires the use of oils, fuels, lubricants, coolants, and other hazardous

[10] For more information on how to conduct an ecosystem service valuation, see Environmental Compliance Factsheet: Ecosystem Services in Environmental Impact Assessment (https://www.usaid.gov/documents/1860/environmental-compliance-factsheet-ecosystem-services-environmental-impact-assessment) and Integrating Ecosystem Values into Cost-Benefit Analysis: Recommendations for USAID and Practitioners (https://biodiversitylinks.org/projects/completed-projects/bridge/bridge-resources/integrating-ecosystem-values-cost-benefit-analysis).

materials. These materials can lead to soil, surface water, or groundwater contamination and harm area flora and fauna.

***Management and Mitigation Measures.*** Mitigation of the ecological impacts from noise, physical disturbance, light pollution, and any released pollutants relies primarily on minimizing the magnitude, areal extent, and duration of such impacts. Impacts may also be reduced by controlling the timing of such impacts, such as by limiting noisy operations to certain times of day or limiting habitat disturbing operations to certain seasons of the year. Mitigation measures should be designed, implemented, and monitored in consultation with habitat and biodiversity experts.

## 4.2 PHYSICAL IMPACTS OF ROAD CONSTRUCTION

### 4.2.1 LOSS OF TOPSOIL

Loss of topsoil may occur during construction from direct removal during land clearing and site preparation or as the result of wind or water erosion. Topsoil is the layer of soil with the highest volume of plant nutrients, biological activity, and organic materials. Consequently, the loss of topsoil can have substantial adverse impacts on the health, quality, and fertility of the soil. Loss of topsoil almost completely eliminates the soil from providing key ecosystem services, including provision of nutrients, water flow regulation, and combatting or deterring pests and diseases. Topsoil loss results in land degradation and decreases vegetation growth and agricultural productivity. The organic matter in topsoil is rich in carbon, so the topsoil may act as a carbon sink. Disturbance of the topsoil can contribute to increased atmospheric $CO_2$ concentrations.

***Management and Mitigation Measures.*** To avoid loss of the productive soil layer, topsoil should be stripped, stockpiled (if required), and ultimately reused at the same or an alternate location. Stripping should be to the depth of the bottom of the uppermost organic layer, typically about 15 cm. The stripped topsoil should be stockpiled in locations designated on site plans and should be properly located, shaped, and managed to prevent erosion by wind or water. Topsoil fertility can be maintained during storage by periodically mixing the upper foot or so of soil into the remainder to aerate the soil, mix in moisture, and redistribute microorganisms. Keeping topsoil stockpiles relatively low and flat, with heights less than 3 m, facilitates periodic mixing.

Topsoil houses many native seeds that are beneficial for vegetation restoration after construction. While revegetation seed mixes often use only a few species, mostly grasses, many native species, including forbs, shrubs, and trees, will emerge from the seed bank of the stored topsoil.

When reusing topsoil, the soil should be uniformly spread to a depth of approximately 15 cm across all applicable flat or low- to medium-inclined (less than 45 degrees) locations that were disturbed during the construction activities. Topsoil may be combined with rock mulch or riprap to enhance slope stability and promote vegetation growth on slopes or in areas subject to intermittent surface water flows. Where quantities of available topsoil are limited, the most critical disturbed areas should be prioritized. If a surplus of topsoil is available, it should be used to improve areas outside of the construction area, such as by supplementing the soil in agricultural plots.

### 4.2.2 SOIL EROSION AND SEDIMENT TRANSPORT

*Figure 25. Exposed Soil During Construction*

Earthworks, including vegetation clearance, grading, leveling, excavation, stockpiling, compaction, and backfilling, can expose soil to rain and wind, change soil structure from mechanical disturbance, and make soil more susceptible to erosion (Figure 25). An analysis of the potential for soil erosion should consider erosion of the road or road components themselves, erosion on lands directly disturbed by the road construction, and erosion due to stormwater runoff from the road or other project land.

The potential for erosion of the road or the road components, such as drainage channels, should be considered during the road design. Particular attention should be paid to geometric design considerations, such as the steepness and length of slopes. The road should be designed with an adequate crown or slope to encourage the water to drain off the road surface, a base layer that promotes drainage and prevents waterlogging of the road, adequate longitudinal and lateral drains to carry water away from the road, and a wearing course that is resistant to forming wheel ruts. The road must be designed with sufficient culverts to prevent water from ponding along the upslope side of the road.

Land clearing, vegetation removal, excavation, and grading activities expose soil and change the magnitude and direction of precipitation runoff. Exposure of bare soil to the impacts of raindrops, repeated wetting and drying cycles, stormwater runoff, and wind can loosen and dislodge soil particles. Stormwater runoff can lead to concentrated flows that create channels and gullies that further concentrate and accelerate flow, increasing the water's erosional forces (Figure 26). Inadequate drainage of exposed areas can lead to water ponding, which further softens soils and makes them more susceptible to erosion.

*Figure 26. Erosion Gully*

Poor site management during construction can lead to a loss of soil as windblown dust or as sediment within surface water flows. Potential impacts of erosion include loss of topsoil, scouring of the landscape, concentration of runoff flows, excessive sedimentation of local waterways, reduction in soil fertility, and changes to site hydrology.

Erosion and sediment transport are also of concern wherever the contractor places temporary or permanent spoil piles. The piles generally consist of loose soils forming steep slopes, which is a combination that is particularly susceptible to erosion.

***Management and Mitigation Measures.*** Exposed soil areas should be limited to the smallest area possible and for the shortest time possible. To the extent practicable, all exposed soil areas should be graded to maintain controlled surface drainage, preferably by encouraging distributed sheet flow. Where flows concentrate, erosion control measures should be put in place to reduce the water velocity, filter out suspended solids, cause the solids to settle out, or direct the flow to drainage channels capable of handling the flow. Erosion control measures also should be placed around the base of spoil piles to manage runoff and contain soil.

Common erosion control measures include the following:

- Silt fencing is commonly used along the downslope edges of exposed soil areas to filter out sediment before it can be transported to undisturbed areas or surface waters. Silt fencing is a tightly woven, synthetic fabric supported by wooden stakes. The bottom edge of the fabric is anchored by burial in a trench to prevent sediment-laden water from flowing beneath the silt fencing.

- Hay bales serve the same purpose as silt fencing. The bales are lined up continuously to form a line of control, often along the downslope boundary of the exposed soil area. The bales are secured to the ground with wooden stakes. As water flows through the bales, soil particles are filtered out. Native grasses can be bundled and staked in place in lieu of hay bales to control sediment transport (Figure 27).

*Figure 27. Native Grasses Used to Filter Runoff*

*Figure 28. Filter Sock*

- Filter socks (Figure 28) are manufactured as woven synthetic fabric tubes typically 15 cm to 20 cm in diameter and filled with a filter material. If the tubes are filled with lightweight materials, such as wood chips or fibers, they can be staked into the ground to keep them in place.
- Straw wattles or fiber rolls are similar in appearance to filter socks; however, the exterior tube has a coarser weave fabric that confines the straw within the tube. Straw wattles should be staked in place to prevent displacement. Depending on the confining fabric, straw wattles may be fully biodegradable.
- Gravel bags are synthetic woven fabric tubes filled with heavier materials, such as gravel, which are held in place by their own weight.
- Erosion control blankets are natural or synthetic materials manufactured in the form of flat blankets that can be rolled out to cover soil requiring erosion protection. They are often used on slopes or in grass-lined drainage channels to protect against erosion before the ground vegetation is established.
- Inlet protection is recommended whenever potentially sediment-laden runoff may enter a stormwater inlet or drain. Inlet protection can be one or more layers of synthetic filter fabric installed over the mouth of the inlet or can be one or more filter socks placed around and upstream of the inlet.
- Mulch can protect against erosion of bare soil by dissipating the impact force of raindrops and by slowing runoff. It is generally only effective on flat or gentle grades and where flow velocities are low.
- Gravel and riprap can provide erosion protection on broad areas of bare soil, in areas of more concentrated flow, and—if the individual rocks are large enough—at points of concentrated discharge.

Where alternative sites are available, siting camps, workshops, storage areas, detours, or other project components that require land disturbance in areas less susceptible to erosion can reduce adverse impacts. For example, sites on flatter ground, sites not affected by large watersheds, or sites with adequate ground cover would be less susceptible to erosion.

In many areas, long-term erosion protection will involve revegetating areas that were disturbed for construction. The disturbed areas should be replanted or revegetated as soon as practical after the construction or disturbance has ended in that particular area. It is not necessary or advisable to schedule all site restoration work at the end of construction.

The contractor should prepare and implement an erosion control plan or a Stormwater Pollution Prevention Plan that specifies the erosion control measures to be used. Site-specific plans with drawings showing the types and locations of proposed erosion control measures should be required before the contractor is allowed to clear a site. In areas of expected or frequent slope failures during construction earthworks, the site-specific plans should include on-site stockpiling of sufficient erosion control materials to provide rapid response.

### 4.2.3 SOIL COMPACTION

Road construction activities can lead to compaction of soil in areas that have vegetation or are planned to support vegetation after construction. Soil may be intentionally compacted along temporary access and haul roads, in laydown areas, and in construction camps to increase the soil's bearing capacity. Unintentional compaction also may occur from the movement of vehicles, construction machinery, the movement or temporary placement of construction materials, or repetitive foot traffic. Soil compaction densifies the soil and reduces the volume of voids in the soil structure.

The reduction in void volume reduces the soil's infiltration capacity, water-holding capacity, and ability to support plant and animal life, including microorganisms, thereby adversely impacting the vegetative growth potential within affected areas.

The reduction in infiltration leads to increased stormwater runoff and increased runoff flow velocities. The greater, faster, and more concentrated flows can increase erosion, especially in uncompacted soils immediately adjacent to the compacted soil areas. The erosion can lead to damage to vegetation and sedimentation of nearby surface water.

***Management and Mitigation Measures.*** Soil compaction may be minimized by identifying and strictly keeping to defined temporary road boundaries throughout the construction activities. Construction sites and laydown areas must ensure appropriate design for drainage and the implementation of sediment controls where necessary. When an area is no longer needed for construction, restoration procedures should include ripping, scarifying, and mixing the soil to a depth of at least 30 cm before spreading topsoil and revegetating. Haul roads or areas that experienced more intense compaction may need to be ripped and scarified to a greater depth. Soil ripping and scarifying should not be done under rainy or wet conditions.

### 4.2.4 STORMWATER RUNOFF AND HYDROLOGY

Many activities associated with road construction affect the quantity and quality of stormwater runoff and can change the hydrological conditions in and downstream of construction areas. Whenever a construction process removes vegetation; disturbs, excavates, places, compacts, or stockpiles soil; or changes an area with a permeable surface to a less permeable one by constructing camp buildings, workshops, or a paved surface, the infiltration characteristics and therefore the runoff characteristics of the area change. Whenever a construction process lowers the ground level, raises the ground level, disturbs a drainage path, creates a drainage channel, builds stormwater detention or retention structures, or alters the flow in a waterway, the hydrology of the area is changed.

These changes in runoff and hydrology can impact groundwater levels, soil moisture content, areas of soil saturation or ponding, surface water levels, and flow rates in streams and rivers. Changes in groundwater levels can affect wells, shallow water pits, or ponds; change flooding potential; and affect water levels in streams and rivers. Increases or decreases in soil moisture content can alter crop irrigation needs and change the potential for wind erosion. Newly saturated or ponded areas can reduce agricultural land or natural habitat while creating breeding grounds for disease vectors, such as mosquitoes. Drying up ponds or saturated areas can disturb wildlife or vegetation or impair a water source used for agriculture or livestock. Increased peak flow rates in streams and rivers increase the risk of flooding, whereas reductions in flow can contribute to water shortages for downstream users or diminish the required ecological flows. Over the longer term, changes in infiltration rates can change groundwater levels and impact water levels in wells.

A road crossing an area with a high water table or a wetland may act like a dam that blocks surface and subsurface water flows. This is especially true where large quantities of material must be added to raise the road above the land surface and where new material must be added periodically to keep the road elevated. Under these circumstances, land on one side of the road can become much wetter than it was before the improvement, while land on the opposite side may be drier. Alternatively, poorly installed culverts can potentially drain wetland areas, which are valuable for the ecosystem services they provide. These impacts can adversely affect crop production, the composition of species in the local ecosystem, and road stability.

Road builders may unintentionally create artificial ponds or other water impoundments by damming gullies or other small catchment areas and from the excavation of depressions in quarries or borrow pits. Without appropriate planning, this can lead to the creation of conditions for vector-borne and waterborne diseases such as malaria. With appropriate foresight and effective management, impoundments may have a beneficial impact by providing water storage capacity to supplement water supplies during dry seasons.

Runoff from paved road surfaces carries contaminants—primarily sediment, oils, rubber-derived compounds, metals, polycyclic aromatic hydrocarbons (PAHs), other organics, deicing agents, and salt—that can degrade receiving waters if the runoff is not treated. Many management and mitigation measures for managing stormwater quantity are also effective in improving stormwater quality.

***Management and Mitigation Measures.*** During the design process, the design team should evaluate the existing runoff conditions and patterns, the potential conditions and patterns during construction, and the post-construction conditions and patterns. Significant identified adverse impacts should be addressed during the planning and design phase to the extent possible.

If the road alignment crosses or otherwise impacts wetlands, care should be taken to minimize altering the site hydrology. Wetland crossings should aim to maintain the natural flow patterns by providing large-opening box culverts, causeway bridges, multiple culvert causeways, and porous rock fills.

Stormwater management can include reducing the runoff by retaining trees, shrubs, forbs, and grasses to capture precipitation; maintaining soil infiltration by minimizing disturbed, compacted, or low-permeability areas; reducing peak runoff flow rates; encouraging sheet flow; and reducing stormwater flow velocity.

Common stormwater runoff control measures include the following:

- Proper grading of a site, including of a dynamically changing site such as an active borrow pit, encourages distributed runoff as sheet flow and minimizes concentrated flow. Concentrated flow has greater velocity and causes more severe erosion. Proper grading can enhance infiltration by maintaining flatter areas, gentle grades, or contoured ridges to reduce runoff velocity. Enhanced infiltration may not be desirable in borrow pits if the soil water content is already high but may be helpful if the water content is below the minimum required for compaction.
- Grass areas or vegetative buffer strips enhance infiltration, reduce runoff velocities, and protect against soil loss. Minimizing the size of any disturbed areas preserves the maximum amount of existing vegetation. Breaking up large contiguous areas of bare soil with vegetated strips helps capture soil particles by reducing the runoff velocity.
- Retention ponds reduce runoff directly by capturing stormwater and storing or retaining it. This reduces downslope or downstream flooding and can make the water available for beneficial use. A retention pond may have a spillway or outlet to control the maximum water level. Because retention ponds capture sediment transported by the stormwater runoff, the ponds may need periodic sediment removal to maintain their storage capacity.

- Detention ponds are similar to retention ponds except that they are normally dry. Detention ponds have a low-level outlet that lets water out but at a much slower rate than it comes in. This reduces the peak runoff flow by detaining the stormwater for later release. Detention ponds also trap sediment from the runoff.
- Check dams are small riprap or gravel dams constructed across open channels to slow the velocity of the water (Figure 29). In unlined open channels, they may be permeable and are usually designed to be overtopped without damage. Frequent, closely spaced check dams are generally more effective than larger dams spaced farther apart.

*Figure 29. Check Dams*

- Silt traps are depressions or pits in unlined channels or engineered pits in concrete channels that capture sediment in the discharge water. Silt traps are often used in conjunction with check dams in open channels or with short walls or other obstructions in concrete channels. When the discharge water reaches the check dam or wall, the velocity is reduced as the water backs up. The lower velocity induces the entrained soil particles to settle in the silt trap, while the cleaner water passes over the top of the check dam or wall. Silt traps are useful during construction when labor is readily available to periodically remove the trapped silt. Without periodic cleaning, silt traps simply fill with soil and become ineffective, so they are not appropriate long-term solutions for sediment transport problems.
- Stepped channels replace long, sloping channels with a channel constructed as flatter sections interspersed with abrupt drops (Figure 30). The flatter, disconnected channel sections diminish the buildup of momentum in the discharge flow. The abrupt drops are designed to dissipate energy by inducing turbulence. The effect is to reduce a single, long, high-energy stream to a series of shorter, slower moving streams, each ending in a low-energy waterfall.

*Figure 30. Stepped Drainage Channel*

- Stilling basins are often constructed at the end of a drainage channel to dissipate the energy of the stormwater flow by creating a pool deep and wide enough to reduce the flow's turbulence and velocity. Reducing the velocity decreases the likelihood of scour at the discharge point.

- Diversion trenches reduce stormwater impacts on the construction site by intercepting the water on the upslope side of the site. They are typically temporary open channels designed to intercept flow along their length and direct it in a controlled manner to a safe discharge point. Diversion trenches may be particularly beneficial on the uphill side of borrow pits, quarries, and camp areas. Although diversion trenches may also be helpful during construction along the crest of a slope above the road alignment, the design should consider whether a permanent open channel would be more appropriate.
- Diversion berms serve the same purposes as diversion trenches and may be more suitable, depending on the topography and available soil type. Diversion berms are built upslope from the area to be protected and divert water away to a suitable discharge point.

Many of the contaminants in road runoff bind to soil particles, so many of the mitigation measures above are also traditional best practices for treating stormwater runoff. Along low-volume roads, grass swales can be an effective and economical means of filtering out sediment and contaminants. Along more heavily traveled roads, vegetated buffer strips, detention ponds, and retention ponds are commonly used to improve discharge water quality where land is available. Where conditions are favorable, constructed wetlands can be designed to capture or break down runoff contaminants. In urban environments, more elaborate filter systems or specialized equipment may be needed to handle the runoff concentrations in a compact space.

Treating road runoff from bridge decks can be particularly challenging because the untreated water should not run off into the stream or river below. Runoff from bridge decks is usually piped to the ends of the bridge and treated on land.

#### 4.2.5 ACID ROCK DRAINAGE

In areas where the geology includes rock that is rich in sulfide minerals, disturbance and exposure of the sulfide-rich rock can lead to the generation of acidic runoff. Rock may be disturbed and exposed when making cuts along the road alignment to achieve the design grade. Sulfide-rich rock could also be excavated in quarries, but such rock would generally become waste rock because its chemical properties would make it unsuitable for most engineering purposes. Sulfide-rich rock is common in areas of copper, lead, zinc, gold, or silver mining.

Sulfide minerals form below the earth's surface under reducing conditions, i.e., environments with insufficient oxygen and moisture to facilitate oxidation. When rocks containing these minerals are exposed in road cuts or are excavated and placed in waste rock piles, they can be exposed to atmospheric oxygen and moisture, which permits rapid oxidation. The oxidation process releases sulfur that combines with oxygen and hydrogen to form sulfuric acid ($H_2SO_4$). The sulfuric acid can produce acidic drainage from the exposed rock in the road cuts or from the waste rock piles. The acidic nature of the drainage not only impacts the pH of receiving waters but also increases the mobility of metal contaminants, with detrimental effects on flora, fauna, and potability.

***Management and Mitigation Measures.*** Acid rock drainage can be a long-term problem, so the best mitigation strategy is to avoid disturbing any rock with acid-generating potential. To the extent possible, siting decisions should avoid areas with sulfide-rich rocks or, when that is not feasible, design the alignment and grade to avoid or minimize cuts in such rock. Quarries should be selected that do not require removing sulfide-rich rock overburden. The cost of the additional haul distance may be less than the cost of mitigating an acid rock drainage issue for 30 years or more.

Where road construction activities unavoidably lead to acid rock drainage, the drainage can sometimes be neutralized by contact with rock with acid-neutralizing potential, such as limestone. This is unlikely to be affordable or successful over a large area, such as a long stretch of road, but could be appropriate for a limited site such as a quarry waste rock pile. Even in such cases, the limestone becomes less effective over time and may need to be replaced periodically. The site would also require long-term environmental monitoring to ensure that the mitigation measures remain effective.

The complex issue of acid rock drainage has been studied extensively in the mining industry where it is also known as acid mine drainage or mining influenced water. There is an extensive body of knowledge regarding the potential impacts of and mitigation measures for acid rock drainage in the mining and mine reclamation literature. (M. Bradley 2014), (Bradley and Worland 2015)

### 4.2.6 SOIL CONTAMINATION

Contamination of soil during road construction may result from improper transfer, storage, use, and disposal of oil products and other hazardous materials, including fuel, lubricants, paints, and chemicals, or from inappropriate waste management. Soil contamination may also result from improper discharge of wastewater. These impacts are particularly associated with construction camps and staging areas where refueling and maintenance of equipment takes place and where the majority of potential contaminants are stored and used. Soil contamination is often the result of accidental spills and uncontrolled leaks.

Contaminated soil can lead to adverse ecological or human health impacts by direct exposure of plants or animals to toxic substances; long-term leaching of soil contaminants into surface water or groundwater; inhalation or ingestion of contaminated dust particles, particularly when soil is disturbed and dispersed during construction activities; direct consumption of contaminated soils (e.g., by young children); consumption of produce—particularly root crops or tubers—grown in contaminated soil; or skin rashes or blisters from direct dermal contact.

***Management and Mitigation Measures.*** Soil contamination can be minimized by careful planning, proper training, consistent use of risk mitigation procedures, engineering controls, and effective spill response. The primary engineering controls are secondary containment and spill protection.

*Figure 31. Use of Drip Pan During Vehicle Maintenance*

Secondary containment provides a redundant containment structure if the primary storage container fails or if there is a leak or spill. The secondary containment structure must be large enough to retain the volume of the maximum possible spill plus a reasonable safety factor, including any interconnected tanks and associated piping that could contribute to the leaked volume. Effective measures could include metal pans under machinery or generators, concrete slabs with surrounding vertical concrete walls, surface drainage and collection systems, or other tailored solutions relying on sufficiently impermeable materials. Containment structures should be routinely monitored for any cracks, microfractures, or other areas prone to breach and leakage. Temporary secondary containment during the transfer of hazardous materials can be provided by metal drip pans that capture spills before they can reach the soil (Figure 31).

Mitigation measures against soil contamination from wastewater discharges center on procedures which ensure that discharged water meets acceptable standards. This may mean capturing and treating wastewater streams before discharge or designing on-site treatment systems such as septic tanks and leach fields to promote biological treatment.

### 4.2.7 SURFACE WATER IMPACTS

Many different road construction activities have the potential to cause negative impacts on surface water. Road construction may also alter the physical and chemical environment, such as water quality and oxygen levels (Rao and Girish 2007). Impacts may arise from direct or indirect discharge to surface waters from the following sources:

- Accidental leaks or spills of chemicals or hazardous materials, such as oils, lubricants, or fuel;
- Improper chemical/hazardous material transfer, storage, and disposal;

- Waste materials that are not stored and disposed of properly;
- Improper discharge of wastewater;
- Washdown water from construction equipment; and
- Increased turbidity caused by earthworks and other construction activities.

Unintentional discharge of potentially harmful substances from accidental leaks, spills, or other releases of petroleum products, other chemicals, hazardous materials, or wastes most frequently result from some combination of inadequate transfer, storage, and disposal procedures; inadequate engineering controls; and inadequate training. Although accidental releases are most commonly associated with liquids, spills of other materials—such as cement powder or herbicides—can be washed away by stormwater runoff and contaminate surface waters. The chemicals from these sources may have toxic effects on aquatic species or contaminate water used by inhabitants farther downstream.

Intentional releases that impact surface water commonly arise from the improper discharge of wastewater used for activities within the camps or used to clean construction equipment. Wash water used to clean equipment used to mix or place concrete, including trucks, mixers, shovels, and other tools, contains cement and fine soil particles and often has a very high pH. The fine particles increase the surface water turbidity if they remain suspended and can adversely affect plants, benthic species, and breeding habitat if they settle to the bottom. These releases can be avoided by instituting proper procedures, engineering controls, and worker training.

The third category of impact relates to increased water turbidity and sedimentation due to disturbance of soil within or adjacent to surface waters or due to nearby soil erosion associated with construction activities. Construction of bridges or culverts may directly disturb the sediment in rivers or streams, increasing the suspended solid concentration. Construction along and near the banks of waterways, such as the construction of bridge support structures, not only increases the risk of erosion and siltation but also has the potential to destabilize existing topographic and geographic features, change the hydraulic flow regime, and modify the river morphology. Soil disturbance can also release pollutants from any previously contaminated soil that is disturbed during construction.

Construction activities can also impact surface waters by direct consumption, reducing the amount of water remaining for other users or for ecological flows. Substantial quantities of water are often needed to achieve the proper compaction water content for earthworks; to suppress dust from construction activities and traffic along the project road and detours and within camps, quarries, and borrow pits; for concrete operations; and for the operation of camps. Although this demand for water is temporary, it may significantly affect local water supplies. In arid and semi-arid areas, drawing water for road construction may decrease the amount of water available for aquatic species, farm production, and drinking, especially if the water is taken during dry seasons.

***Management and Mitigation Measures.*** Procedures, engineering controls, and training provide a multi-layered defense against accidental releases. All areas of the construction site that have materials or waste in liquid form should have proper engineering controls to ensure that these materials and wastes are stored in a manner to prevent accidental releases from leaks and spills. The procedures and training on the use of such materials should emphasize that these materials should only be used for their intended purpose and in their intended locations. Any leaks or spills should be immediately contained and cleaned up. Spills of powdered materials also should be contained and cleaned up to prevent being carried away by stormwater runoff.

Intentional releases are usually the result of failing to consider the impacts of discharges. These releases are best addressed during the planning and design phase by explicitly identifying and considering all discharges from the construction activities, including operation of the camps and cleaning of construction equipment, and the potential impacts of those discharges. Engineering controls, operating procedures, and training should be put in place to ensure that any significant potential impacts are mitigated. Controls may include the collection of discharges in tanks for offsite disposal at approved facilities, the construction of septic tanks and leach fields to manage discharges on-site, or other capture or treatment technologies. Some waste discharges may be considered benign and acceptable for direct discharge and infiltration, e.g., discharge from handwashing stations, but this should be explicitly documented.

Impacts from sediment deposition and increased turbidity are mitigated by measures to reduce soil erosion and to control stormwater runoff. These measures are particularly important whenever construction takes place near surface water bodies because eroded soils are more likely to be discharged into the nearby water. The measures must be protective not only during working hours when construction activities are occurring and are easily monitored but also when the site is unattended during non-working hours, weekends, holidays, or periods of inclement weather – especially heavy rains. If possible, inspections of the effectiveness of erosion controls should be undertaken during heavy precipitation events if doing so can be done safely.

Whenever construction takes place in a waterway, coffer dams may be needed to divert the water and provide a dry working area and silt curtains may be needed to prevent the movement of disturbed sediment downstream. Any structures, such as bridge abutments or culverts, built in a flowing waterway will alter the flow. Erosion around the structures, or scour, can remove large quantities of sediment if the scour protection is inadequate. Riprap or concrete mats are often used to armor bridge abutments, bridge piers, and exposed riverbanks to reduce scour and erosion. Any changes in the channel width, depth, slope, or roughness will induce changes in the flow patterns. These changes can alter the stream morphology until the stream and the streambed reach a new steady state.

Water consumption impacts must be addressed through adequate advance planning and consultation with other water users. If water is scarce or in high demand during particular time periods, the contractor may be able to store water in advance to mitigate peak water demands. The project may need to implement additional controls if community potable water sources are at risk, such as frequent testing or the temporary provision of an alternate water source, to guarantee a supply that meets drinking water standards.

### 4.2.8 GROUNDWATER IMPACTS

The potential surface water impacts and mitigation measures associated with unintentional and intentional releases also apply to groundwater. Groundwater impacts may not be as apparent and may persist for much longer periods of time. Soil contamination can also create a long-lived source of pollution that causes long-term contamination of groundwater. Any deleterious substances that get into groundwater can migrate to a surface water body or can cause exposure if water is extracted from wells. In karst terrain, contaminants can migrate through the interconnected sinkholes, solution cavities, and caves at speeds and distances comparable to migration in surface water so additional precautions near known or suspected points of entry to the subterranean network are warranted.

Construction activities that alter land use, create depressions, change runoff patterns, or directly alter the hydrology with retention or detention ponds can affect the amount of infiltration and groundwater recharge. Groundwater extraction from wells for camps or other construction uses can lower the local water table and can adversely impact nearby wells by reducing yields or causing the wells to go dry.

***Management and Mitigation Measures.*** During the planning phase, the potential changes to groundwater recharge and use should be considered and evaluated for their overall and local impacts. In wet seasons, retention or recharge ponds can increase groundwater infiltration and raise the groundwater level, making more water available during dry seasons. Plans may need to be modified if sufficient groundwater is not available for both existing and construction uses.

### 4.2.9 AIR EMISSIONS

Air emissions such as dust, particulates, combustion byproducts, and odor have the potential to reduce air quality and impact nearby sensitive receptors if not appropriately mitigated and managed. Potential sources of impacts on air quality include the following:

- Earthworks, such as site preparation, grading, excavation, or soil placement and compaction;
- Loading, transport, and unloading of soil;

- Dust generated from material stockpiles;
- Loading and unloading of powdery, dry bulk materials or wastes;
- Operations with cement, including small-scale mixing and large batching plant operations;
- Quarry blasting, rock crushing, and screening operations (Figure 32);
- Exhaust emissions from trucks, heavy construction equipment, or other construction vehicles;
- Operation of diesel generators, pumps, and other diesel-based construction machinery; and
- Volatile organic compounds (VOCs) from fuel, oils, solvents, bitumen, and paints.

*Figure 32. Dust from Rock Crushing Operations*

Potential impacts from dust include the following:

- **Health and Safety.** Dust may impair breathing for workers and nearby residents and, in severe cases, cause long-term lung damage. Poor air quality due to fine particulates can be more dangerous to those with previous breathing issues, such as the elderly or asthmatics.
- **Traffic and Pedestrian Safety.** Dust can reduce road visibility for drivers and pedestrians. Fine particle clouds from truck traffic on dry dusty roads can remain suspended and reduce visibility for surprisingly long times and distances. In Figure 33, a cloud of dust trails a construction truck—which is no longer in sight—impairing visibility for the vehicles behind it. The inset figure shows a barely visible pedestrian walking along the edge of the road.
- **Land Animals.** Animals may abandon habitat impacted by dust. Avian nesting may be interrupted or may not occur at all. The particulate matter forming the dust harms mammalian respiratory functions.
- **Aquatic Ecology.** Dust blowing onto watercourses may damage aquatic ecology by increasing sedimentation, reducing sunlight, and suffocating fish.
- **Plant Damage.** Dust interferes with plant photosynthesis and can retard pollination. Dust can impair plant and fruit growth, especially dust that is highly alkaline, such as limestone and cement dust. Long-term deposition of dust is often evident near quarry operations and cement batching plants. For example, the left side of the tree in Figure 34, which faced a cement batching plant, is nearly dead and devoid of leaves due to exposure to alkaline cement dust. The right side of the tree, especially the higher parts exposed to less dust, has healthy green foliage.

*Figure 33. Impaired Driver Visibility from Traffic Dust*

- **Increase in Runoff.** Dust deposited during or ahead of a light rainfall can cause the soil surface to form a crust, increasing stormwater runoff.
- **Social Impacts.** Persistent dust generation from construction operations or, more commonly, traffic on unpaved roads through settled areas can pose a grave annoyance to local people in addition to the health risks. Dust can coat outdoor laundry, penetrate homes and businesses, and cover vehicles. Persistent or frequent dusty conditions can induce residents to alter their lifestyle by avoiding impacted homes or businesses or reducing outdoor activities.
- **Damage to Equipment.** Dust can increase the abrasion of moving parts and clog air filters in motorized equipment, construction vehicles, and private vehicles.

*Figure 34. Tree Damage from Cement Batching Plant Dust*

Evaporation of fuel from fuel storage tanks, fueling facilities, vehicles, and equipment releases volatile petroleum hydrocarbons into the air. Additional VOCs can be released from oils, solvents, and paints. These volatile compounds decrease the air quality, contribute to smog, and can break down into harmful ground-level ozone. Vehicle and heavy equipment exhaust emissions can lead to increases in levels of nitrogen oxides (NOx), sulfur dioxide ($SO_2$), particulate matter (PM10 and PM2.5), and carbon monoxide (CO). Diesel generators are the largest contributors of stationary emissions and are prevalent at work sites, field offices, construction camps, workshops, quarries, and concrete and asphalt plants. In cold weather, emissions from heating systems in field offices, camps, and workshops can also be significant contributors. Asphalt plants and asphalt paving operations will also generate emissions of organic compounds, PAHs, VOCs, and odors. Waste accumulation and disposal areas and improperly designed or maintained sanitation facilities can also generate obnoxious odors.

Greenhouse gas emissions from construction activities contribute to atmospheric $CO_2$ increases associated with global warming. Potential sources of emissions include the manufacture and use of materials such as asphalt, concrete, lime, and steel; energy production; internal combustion engines in vehicles, construction equipment, and electric generators; and refrigerants in office building or vehicle cooling systems.

***Management and Mitigation Measures.*** The most common mitigation measure for controlling dust from earthmoving operations; soil loading, transport, and unloading; material stockpiles; and quarries is the application of water (Figure 35). Water is used to raise the moisture content of the soil and to bind the fine soil particles through capillary attraction. In hot, dry, or windy settings, water may need to be applied many times throughout the day. In quarries, fixed water systems may operate on a near continuous basis to generate a water mist whenever crushing or screening operations generate dust. For powdery materials that cannot get wet, such as cement, mitigation measures may include engineering controls in areas where cement is transferred to shield the loose cement from the wind.

*Figure 35. Water Truck Applying Water for Dust Control*

Chlorides, such as calcium chloride or magnesium chloride, where available, are one of the most commonly used dust suppressants after water alone. Lignins and plant resins are also occasionally used. Many dust palliative and soil stabilization products are on the market, but their cost-effectiveness depends on the initial construction cost, maintenance, and effective life of the product (until reapplication is needed) (Jones 2017).

During construction, greenhouse gas emissions can be minimized by using energy-efficient equipment, using properly sized equipment, maintaining the equipment engines in good working order, using biofuels if available, and limiting idling of equipment when not actively working. Effective traffic management can also help minimize greenhouse gases by avoiding unnecessarily long delays and engine idling.

#### 4.2.10 NOISE AND VIBRATION

Noise and vibration impacts may be produced by various construction activities involving motorized construction equipment; powered machine tools; motor vehicle traffic; diesel generators; and operations such as pile driving, blasting, and rock crushing. Noticeable vibration created by impact pile driving, soil compaction with vibratory rollers, or the passage of heavy trucks can disturb wildlife, annoy nearby residents, and damage structures. Excessively high noise levels can damage the health of local residents and road construction workers and can lead to permanent hearing loss.

Construction noise and vibration levels vary by frequency, duration, and intensity. The impacts diminish with greater distance between the source and the receptor. Construction noises may be perceived as more intense if background noise levels are low. Vibrations can travel substantial distances through the subsurface. Impact pilling done in the water for the construction of bridge support structures can have adverse effects on freshwater and marine animals. Repetitive and persistent vibration from power tools can result in worker hand or arm injuries.

***Management and Mitigation Measures.*** Larger road construction projects may require performing baseline monitoring and noise and vibration modeling during the planning and design phase to identify sensitive receptors (e.g., settlements, dwellings) within minimum distances from alignment boundaries and for different construction activities. It may also be necessary to perform independent periodic noise and vibration monitoring during construction to demonstrate compliance with noise and vibration limits. National guidelines and established noise and vibration limits should be followed.

Noisy equipment and operations should be located as far away from receptors as practicable and positioned to direct noise away from populated areas. Temporary noise barriers made of plywood or acoustical blankets can be used around noisy operations where necessary to comply with noise limits. In some cases, material stockpiles and other structures can be used to screen noise-sensitive receptors from on-site construction activities. All construction equipment should be inspected at periodic intervals to ensure proper maintenance and presence of noise control devices (e.g., mufflers and shrouding).

In general, operating equipment, machines, and power tools should be restricted to normal daytime working hours. Equipment and construction plants should be shut down or throttled down between work periods as much as practicable. The transportation of materials on-site and offsite through existing communities during nighttime hours should be prohibited.

Nearby residents should be informed in advance about noisy activities during various construction phases. Complaints should be recorded and responded to in accordance with the established grievance redress mechanism (GRM).

## 4.3 WASTE MANAGEMENT IMPACTS OF ROAD CONSTRUCTION

Because of the volumes and varieties of the components of the road construction waste stream, the contractor should develop an Integrated Waste Management Plan that estimates the types and quantities of all the potential wastes. The plan should detail the disposition of each type of waste, means of transportation, final location, and parties responsible for each component of the waste stream. All waste shipments should have a manifest system to confirm delivery and to document the waste quantities.

The waste management plan should indicate how the project will manage each waste component in accordance with the USAID Waste Management Hierarchy, listed below from the most preferable to the least preferable alternative:

- Waste prevention
- Waste reduction
- Waste materials reuse
- Waste recycling
- Waste recovery
- Waste treatment
- Waste disposal

### 4.3.1 SOLID WASTE

Solid non-hazardous waste streams from road construction projects can include waste streams normally associated with a community the size of the workforce plus the more industrial waste streams associated with the construction activities. These waste streams often include the following:

- Vegetation waste, e.g., timber waste from tree felling and site clearing
- Demolition waste from the removal of pre-existing or temporary structures and construction waste from repairs or modifications to camp buildings. These wastes may include wood, sheetrock, plaster, corrugated metal sheets, fencing, wire, piping, tiles, or other building materials.

- Wood from temporary forms for cast-in-place concrete
- Concrete waste
- Scrap rebar, reinforcing mesh, and tie wire
- Wastes from workshop, machining, and equipment repair operations such as ferrous scrap, mechanical parts, scrap tires, welding electrodes, and empty metal or plastic paint cans
- Empty cement bags
- Common trash from field offices and construction camps consisting primarily of paper, cardboard, plastic, and metal cans
- Food waste from construction camps

*Figure 36. Temporary On-Site Storage Area for Construction Waste*

***Management and Mitigation Measures.*** Non-hazardous solid waste should be routinely collected and segregated by waste type to facilitate reuse, recycling, or disposal (Figure 36). The waste storage areas and containers should protect the waste from dispersion by wind or surface water runoff, animal incursion, and, if appropriate, protection from rainfall. The easiest waste to recycle is scrap ferrous metal because it normally has commercial value and can be sold. Other metals such as copper or aluminum may have commercial scrap value and are often handled by the same companies that purchase ferrous metal scrap. Depending on the locality, there may be programs for recycling other materials, such as paper, cardboard, and plastic. The project waste management plan should consider recycling even if it is not the lowest cost alternative because of the reduced environmental impacts.

Vegetation waste may include trees and smaller vegetation. The wood in the trees may have value as fuel. If local residents use wood for heating or cooking, the project may allow access to wood and brush piles and allow residents to remove what they can use. If liability issues are a concern, access could be granted to one or more qualified persons or entities who can cut up the felled trees and sell the wood. The remaining brush, leaves, and grasses are often stockpiled or spread to decay in place if suitable space is available. Wood and brush can also be chipped or mulched into useable products or to facilitate decay. Some types of vegetation may be suitable for composting. If the wood piles are located in an area where termites are common, the impacts of encouraging termite colonization should be considered.

If the project area has existing, effective facilities for waste disposal, the other components in the solid waste stream should normally be sent to those disposal sites because they are apt to be better engineered, controlled, and monitored than other alternatives. If effective waste facilities are not available in the road project area, it may be advisable to transport the waste to a more distant urban center that has such facilities. The alternatives described below may be viable options where no effective waste facilities are available and if permitted by local regulations.

If scrap lumber, paper, or cardboard cannot be recycled or disposed of at an established solid waste facility, it can be burned or buried on-site if allowed by local laws and regulations. Burning should be done in an incinerator with air flow controls, a chimney, and screening to prevent flyaway ash or cinders. Proper siting, safety setback distances, and fire protection equipment and worker PPE would be required.

Any waste burial areas must be sited in areas with no flooding risk and away from surface water bodies or water wells. Burial areas should only accept biodegradable waste that is not contaminated with any noxious substances and should be operated to prevent waste scattering or animal attraction by frequent and liberal application of intermediate soil covers. The burial areas should maintain at least a 60-cm final soil cap over the top layer of waste and may need additional protection against burrowing animals, such as a layer of riprap. The use of moderately sized cells that can be closed sequentially is preferable to a single, large, open cell. Upon closure, all burial areas should be clearly marked in the field to alert future land users that waste is buried. Use of marking tape or a geogrid within the final cap is also encouraged to alert anyone digging in the area if the surface signage is removed. The burial areas should be marked on the "as built" site plans as a permanent record of the waste burial sites.

Food waste can be buried but should be buried in a separate location or cell from other trash. Food waste dumped into a burial pit should be covered immediately with a layer of intermediate cover soil to minimize odors and to isolate the waste from insects and other vermin. At the end of the day, a thicker layer of cover soil is advisable. If burrowing animals are found to expose or access the waste at night, the daily cover may need to include gravel or other materials to impede digging. The final soil cap needs sufficient thickness and additional protection, such as a layer of riprap, to permanently isolate the waste from burrowing animals.

Concrete waste, whether from demolition or excess mixed concrete, is relatively inert and can often be mixed with soil and used as common fill material. Broken concrete should not be used alone as fill because it is apt to contain voids that will eventually become filled with overlying soil, creating surface settlement or sinkholes. If the concrete is broken or crushed into large gravel or riprap-size particles, it can be mixed with soil and used in the cover layers for buried waste cells.

Cement for road projects in remote areas is often transported in bags for logistical reasons. The bags currently used to package cement are typically paper or polypropylene, although newer polyethylene bags are also available. Biodegradable paper bags can be disposed of in several ways along with regular solid waste. Polypropylene and polyethylene bags can be recycled or landfilled. They should not be buried on-site or burned.

Scrap tires can be difficult to dispose of properly. They should not be burned, with the limited exception of burning in properly engineered and operated waste-to-energy facilities. Tires should not be buried because they release toxins and buried tires tend not to remain buried. The best option is transporting the scrap tires to a tire recycling facility even if this option entails significant transportation costs. At a tire recycling facility, the steel reinforcement is removed from the tire, the tire is shredded, and the rubber is processed for reuse.

### 4.3.2 FUEL LEAKS AND SPILLS

Inappropriate transfer, storage, use, or disposal of fuel can cause contamination of soil, surface water, and groundwater. Although fuel storage may be concentrated in one or a few locations, the vehicles and equipment using the fuel are dispersed across the entire project area. The presence and use of fuel also creates an elevated fire risk.

***Management and Mitigation Measures.*** Fuel storage areas must be designed with fire safety in mind. Fuel storage facilities should be sited far enough away from buildings or equipment that the radiation from a fuel fire will not cause additional fires, damage, or harm to people. Fire suppression systems should be adequately sized for the type and maximum amount of fuel to be stored and be regularly inspected and tested. Appropriate chemical fire extinguishers should be readily available at all locations where fuel is used.

Fuel storage areas should be sited away from sensitive receptors, especially surface water bodies. Fuel storage areas must be designed with environmental safeguards in mind, primarily by incorporating secondary containment to capture and hold the entire volume of fuel if the primary containment fails. The primary containment includes not only the storage tank(s) but also all the interconnected piping and pumps connected to the tanks. Even a simple break in a small pipe can drain a large fuel tank, so the secondary containment design and size must consider all potential failure modes.

If underground fuel tanks are used, secondary containment would require either a watertight vault or a double-walled tank, which may be directly buried. In areas of high groundwater, permeable soils, or proximity to surface waters or drinking water wells, the use of underground tanks may be precluded. When underground tanks are removed at the end of construction, the surrounding soil should be inspected and tested to identify any leaks.

Fuel spills are most common at fueling facilities and wherever equipment is refueled. Even individually small spills can lead to cumulatively significant contamination if they are repeated in the same location over a long period of time. Therefore, permanent fueling locations must be designed with a low-permeability surface, usually concrete, to prevent infiltration of spilled fuel into the soil or groundwater.

In the field, stationary equipment such as pumps and generators can incorporate permanent drip pans to capture refueling spills or leaks from fuel lines. Portable drip pans should be used when refueling mobile equipment. Vehicles and equipment should be inspected regularly to check for leaks. Fuel should only be transported in containers which are designed for that purpose and are clearly marked with the fuel type, fuel quantity, and appropriate safety warnings.

Even with proper fuel storage, refueling practices, and inspections, leaks or spills are apt to occur. Therefore, spill response plans and training should be developed and implemented to familiarize staff with spill response procedures and cleanup materials. Spill response kits for gasoline and diesel fuels may contain single-use absorbent materials, additives to accelerate microbial degradation, absorbent pads or socks, floating containment booms for spills in or near water bodies, shovels, or other tools to manage soil, PPE, and containers or bags for used spill recovery materials.

### 4.3.3 HAZARDOUS MATERIALS AND WASTE

Beyond fuels, improper storage, handling, transfer, use, or disposal of other hazardous materials (e.g., oils, greases, hydraulic fluids, bitumen, paints, adhesives, solvents, pesticides, and a variety of specialty products and chemicals) during construction activities could lead to the generation of hazardous waste and the potential contamination of soil, surface water, and groundwater. Misuse of such materials could result in fires, spills, leaks, worker exposure, or potential public or ecological exposure (Figure 37). Other examples of hazardous waste may include empty containers from hazardous materials, spent oil filters, absorbent materials that have been used to clean up spills, and contaminated soil.

*Figure 37. Bitumen Truck on Fire*

***Management and Mitigation Measures.*** Wherever practical, the use of hazardous materials should be minimized or avoided. When their use is required, all transfer, storage, use, and handling of hazardous materials should be governed by a hazardous materials management plan, which should establish standard operating procedures for each hazardous material used on the project.

Hazardous materials must always be stored and transported in a properly labelled original container suitable for the waste type and quantity. They should never be stored or transported using recycled food or beverage containers.

Hazardous wastes should be segregated, clearly labelled, and stored appropriately based on the waste type. Incompatible wastes, such as acids and bases or oxidizers and fuels, should not be stored near each other. Waste should be stored in containers suitable for the waste type and quantity. The waste materials must be protected from rainwater, erosion, and mixing with stormwater runoff. Secondary containment may be required for many types of hazardous waste. Flammable wastes should not be stored near areas of high heat or potential ignition sources such as welding or metal grinding operations. Hazardous materials and waste storage areas should be routinely monitored for good housekeeping practices, proper storage and access control, any evidence of spills or leaks, and an evaluation of whether any materials are no longer needed.

Empty hazardous material containers, especially empty bitumen drums, should be rendered unusable such as by puncturing holes in the containers before placing them in temporary on-site storage to prevent repurposing by locals for the storage of food or water.

Hazardous waste should be handed over to licensed companies authorized for their transportation and disposal. Best practices include the use of a waste manifest system, chain-of-custody documentation, and maintaining records of all hazardous waste shipped offsite. If the country of operation does not license hazardous waste transporters or disposal facilities, the contractor would be responsible for the proper handling, transportation, and disposal of the waste in accordance with host country laws and regulations and in alignment with internationally recognized best practices.

#### 4.3.4 SANITATION WASTE

Road construction activities and the operation of temporary worker camps, in particular, may cause impacts from the generation of raw sewage and wastewater effluent. Poor sanitation and lack of proper wastewater management at the workers' camp may create conditions for vermin and other disease vectors to multiply and spread infection. This may lead to the transmission of diseases by the workers and increase public health risks. The discharge of sewage effluent or other untreated wastewater can contaminate soils, surface water, and groundwater, with potentially significant impacts on the environment and people. Fecal contamination of water used for drinking or food preparation is a common cause of cholera and dysentery.

***Management and Mitigation Measures.*** Proper sewage collection and disposal systems must be made available to prevent the spread of disease and the polluting of water resources. Camps and staging areas must have proper sanitary facilities, such as engineered septic systems and leach fields, to manage sanitary wastes and to prevent indiscriminate wastewater discharges (Figure 38). Surface water runoff should be prevented from flowing into workers camps to avoid carrying away sanitation waste contaminants.

*Figure 38. Sanitation Facilities and Septic Tank at Quarry*

Sanitation facilities and handwashing stations must be provided everywhere along the road project where construction crews are working. This can be challenging for crews whose locations change frequently. The use of portable toilets is a common practice where adequate maintenance and proper disposal of sewage is available but may not be practical in remote areas. Open defecation is not an acceptable practice. In rural areas, the construction of temporary pit latrines may be necessary, especially at bridge and culvert sites where crews may be working over an extended period. Simple pit latrine designs are available that incorporate features for improved privacy, sanitation, ventilation, and insect control. Units built on a lightweight slab or other rigid base can be easily transported to new locations when necessary, requiring only the digging of a hole at each new location (Figure 39, left photo). Privacy screens around a temporary pit latrine can be constructed out of locally available materials (Figure 39, right photo). Any toilet facilities must be located sufficiently far from surface water bodies and water wells to prevent contamination, including any contamination during heavy rainfall events. In more populated areas, it may be possible to arrange for the use of sanitation accommodations at public buildings or other existing facilities, possibly by direct compensation or by providing cleaning services.

*Figure 39. Temporary Pit Latrines*

#### 4.3.5 WASTEWATER

In addition to sanitation wastewater, wastewater is generated from various road project activities, including washing vehicles and equipment; washing tools, equipment, and mix trucks from concrete work; releasing rainwater captured by secondary containment structures; and discharging gray water from camp kitchens, accommodations, and cleaning activities.

Road construction involves many earthmoving activities, both large scale and small scale, which often cause tools, equipment, vehicles, and PPE such as boots and gloves to be covered with dust, soil, or mud. Routine cleaning generates turbid wastewater streams and mobilizes sediment.

Whenever concrete is mixed or placed, the tools, equipment, and vehicles used to mix, transport, or place the concrete need to be washed to remove the residual concrete. This results in wastewater with a high pH rich in suspended cement particles.

Secondary containment structures are designed to contain liquid, so if they are located outdoors and exposed to precipitation, they periodically hold rainwater. Unless evaporation rates are high, this rainwater may need to be released from time to time. Secondary containment structures are often used at fuel or oil storage locations and the retained water may have contamination from hydrocarbon spills, leaks, or drips.

***Management and Mitigation Measures.*** Proper wastewater management requires that all wastewater streams be identified and contained or discharged in a responsible manner. All water use has the potential to generate wastewater, so all water use on the project should be inventoried and evaluated to ensure that any wastewater discharges from the water use are managed appropriately.

Discharges of any untreated water into surface water bodies should be strictly prohibited and any discharge points should be located a sufficient distance from surface waters to prevent degradation of the water. Treatment may involve solids separation, filtration, or chemical treatment to meet applicable discharge standards. Any wastewater discharges containing floating oil or fuel should pass through an oily water separator to recapture the hydrocarbons before further treatment or release. Concrete wash water may need treatment to lower the pH from the cement.

Infiltration of wastewater into the ground generally has lower environmental impacts than surface discharge because filtration through the soil and microbial activity can improve the water quality; however, the infiltrated water must be free of chemical constituents that can cause long-term groundwater contamination. Infiltration systems may incorporate an engineered settling tank and leach field or may be as simple as a retention pond that captures sediment and permits seepage into the ground.

Water quality testing may be necessary during the planning and design phase to establish a baseline for monitoring during the construction and operation phases based on the scale of the roadwork and the presence of sensitive receptors (e.g., agricultural canals, residences, protected areas). National water quality standards should be followed. U.S. Environmental Protection Agency and other international standards should also be consulted as those standards are sometimes more protective.

## 4.4 HEALTH AND SAFETY IMPACTS OF ROAD CONSTRUCTION

Construction of new roads and rehabilitation of old roads can create health hazards that have far-reaching consequences for both the construction workers and for members of the public living in the local communities or traveling along the roads or detours during construction.

### 4.4.1 WORKER HEALTH AND SAFETY

Road construction workers are potentially exposed to numerous hazards, both from the physical nature of the construction activities and from stressors in the natural environment.

Physical hazards include, but are not limited to:

- Excavation and trench hazards
- Trips, slips, and falls
- Working at height
- Falling objects
- Confined space entry
- Traffic safety
- Working near earthmoving equipment
- Quarry operations
- Working near water
- Workshop safety
- Handling heavy materials and equipment
- Using power tools
- Noise and vibrations
- Electrical hazards
- Fire and chemical hazards
- Hazardous waste

Natural hazards include, but are not limited to:

- Heat stress and heat stroke
- Cold stress and frostbite
- Poisonous or irritating plants
- Insect stings and diseases
- Animal bites, scratches, and diseases
- Communicable diseases

*From a Tanzania road project EMMP:*

*"Risk of being attacked by Crocodiles – The impact shall be mitigated by ensuring that during construction of bridges across the two rivers, local people are consulted to determine sites where the reptiles are commonly seen."*

***Management and Mitigation Measures.***
Road projects, like many construction projects, can reduce work-related injuries, fatalities, and diseases by adopting a culture of "Safety First." This culture requires that personnel at all levels of the organization adopt a genuine attitude that worker safety is paramount. Owners, leaders, supervisors, and forepersons must instill the message that practices or shortcuts that increase the risks to project personnel will not be tolerated and that safe work practices take precedence over both cost and schedule. This is not just an altruistic posture as workplace injuries and fatalities are costly in terms of lost productivity, work stoppages, fines, penalties, and compensation and can expose companies to significant civil and criminal penalties.

Every road project should have a written Health and Safety Plan (HSP) that identifies the potential hazards and details procedures for eliminating those hazards, mitigating risks, or responding to health and safety incidents. Best practices that should be included in the HSP and implemented on the work sites include hazard identification, mitigation, communication, and incident response. Hazard identification includes a review of the activities and an inspection of the conditions at each work site to identify potential hazards. Where possible, potential hazards should be mitigated by changing work procedures, using engineering controls (e.g., physical separation, barriers, emergency shutoffs, lock-out/tag-out procedures), and using proper PPE. Hazard communication involves proper training on potential hazards and mitigation measures, as well as frequent—preferably at least at the start of each shift—tailgate meetings or safety briefings alerting workers to the specific hazards at that site on that day. Response planning involves first aid training, having first aid supplies available, and having procedures in place to provide medical care at the site or to transport injured personnel to a health care facility.

National labor standards and laws on workers' rights and on occupational health and safety need to be followed to avoid accidents, injuries or deaths, loss of labor hours, labor abuses, and unsafe working conditions. A recommended resource is the Core Labour Standards outlined in the International Labour Organization Declaration on Fundamental Principles and Rights at Work (International Labour Organization 2000).

Although by no means exhaustive, the list below provides some additional insights on common road project worker health and safety issues, especially in countries that may not have a strong, institutional safety culture:

- "No PPE, No Work." Instituting and enforcing this simple rule can radically improve PPE compliance at a work site, especially on projects that hire a significant amount of unskilled labor. The prospect of losing a day's wages strongly encourages workers to comply with the site safety procedures and reinforces the Safety First culture.
- The contractor must provide adequate safety boots, helmets, gloves, protective clothes, high-visibility safety vests, breathing masks, goggles, ear protection, safety harnesses, and any other PPE necessary for worker safety. The PPE must be in good condition and replaced as necessary over the duration of the project.
- Everyone on the site must wear proper PPE, including workers, senior contractor staff, engineers, and visitors. The contractor should have extra PPE on-site for visiting officials or other stakeholders—usually hard hats and high-visibility safety vests at a minimum. Senior contractor staff, engineers, and visitors should wear proper footwear. Although safety boots may not be necessary, an engineer who attempts to perform a site inspection wearing sandals undercuts the Safety First message.

- Site supervisors and inspectors should have the authority to shut down a work site if safety procedures are not being followed or if unsafe conditions exist.
- Workers should be encouraged and empowered to notify supervisors and inspectors of potential safety issues and should be protected against any retaliation for doing so.
- Road projects may employ a large, transient workforce and may take years to complete. Interaction between road crew members from other geographic areas and the local population can spread communicable diseases, especially HIV/AIDS and other sexually transmitted diseases (STDs). Road construction projects can also lead to an accompanying influx of sex workers into the area. Where such conditions may exist, road projects should implement HIV prevention programs that focus on HIV/STD awareness education, promotion of condom use, the provision of free condoms, encouraging safe sex practices, and recommending voluntary testing for STDs.
- Local labor practices must be investigated and aligned with international laws and conventions to prevent the use of child labor. Although the direct hiring of child labor by the road project is easy to avoid, additional scrutiny may be required of subcontractors and vendors supplying goods and services to the road project. Vendors may have financial incentives to fill low-skill positions for food services or cleaning services with less expensive but underage employees.
- USAID and its IPs must be aware of local labor practices and ensure that adequate safeguards are put in place to prevent child labor, trafficking in persons, and the use of involuntary or coerced labor. Transient foreign workers may be at risk from coercive practices, such as an employer withholding workers' passports or pay to limit their ability to resign.

*Ensure that adequate safeguards are put in place to prevent child labor, trafficking in persons, and use of involuntary or coerced labor.*

### 4.4.2 COMMUNITY HEALTH AND SAFETY

The greatest potential community health and safety impacts from road projects are physical construction site hazards and traffic hazards. A large construction project, especially in a remote or rural area, can be an attraction to members of the public, especially children (Figure 40). Community members may be unfamiliar with the heavy equipment and other hazards present on the construction site. At least parts of the project are apt to be located close to residential areas, schools, or other population centers (Figure 41), so interactions with the public must be addressed in project planning and execution.

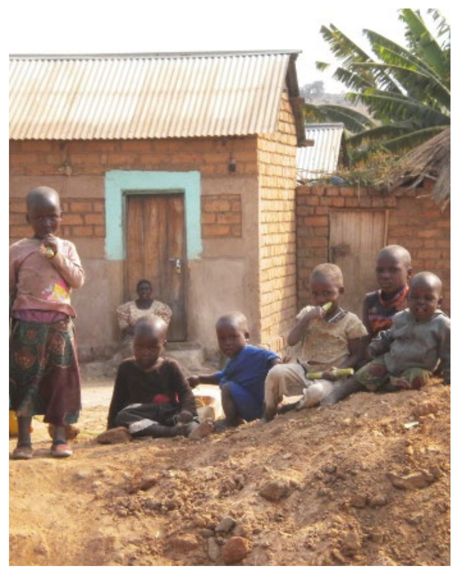

*Figure 40. Children Watching Construction*

Construction hazards may include heavy truck traffic, movement of earthmoving equipment, open excavations, steep slopes, quarries, ponded water, and falls from partially completed elevated structures, such as bridges or retaining walls.

Once the project road is under the contractor's control, the contractor is responsible for traffic safety. This applies not only to the avoidance of accidents with construction vehicles but also to the safe passage of other people using or crossing the road, using or crossing construction detours, or traveling alongside or near the road as pedestrians or bicyclists.


*Figure 41. Safety Markers and Speed Limit Sign near Houses*

In addition to the physical and traffic hazards, potential public safety impacts from road projects include the spread of waterborne diseases such as cholera, dysentery, and malaria from standing water and the spread of HIV/AIDS or other STDs.

***Management and Mitigation Measures.*** Community health and safety begins with education and awareness building. Community leaders, adjacent property owners, local residents, and road users should understand what to expect during the road project. Stakeholder engagement should take place during the planning and design phase. Community outreach may involve public meetings, printed materials, signage, or other means to inform the public of the project location, duration, disruptions, hazards, and mitigation measures. In heavily populated areas or near schools, the public awareness campaign may include presentations in the schools to reach young children directly and to teach them how to avoid the road project hazards. The public should be aware of how to raise safety concerns through the established GRM.

Where appropriate, fencing, warning signs, safety barriers, or security personnel should be put in place to keep the public away from hazardous areas, such as excavation sites, borrow pits, quarries, and other active construction sites. Traffic management plans should be developed and implemented to reduce risks to the community and may include the following components:

- Construction workers should control traffic when construction equipment is entering or leaving the work area.
- Road signs at the periphery of the construction site should warn and direct traffic and pedestrians.
- Speed limits for construction vehicles in residential areas and where other sensitive receptors, such as schools, hospitals, and other populated areas, are located must be strictly followed.
- Controlled crossings may be needed across the road or detours for the passage of crossing vehicles and pedestrians, especially in more populated areas.
- In rural areas, provision may be needed for herds of cows, sheep, or goats to cross the work zone to get to grazing areas or water.
- If pedestrians or bicyclists normally traveled along the edge of the roadway prior to the road project, alternate pathways may need to be developed for safe public movement during construction.
- Warning signs, warning lights, and other traffic aids may need to be illuminated at night.
- In dusty conditions, vehicles should be encouraged to drive with their headlights on for better visibility.

*In Tanzania, police would not let contractor vehicles drive with their headlights on during the day because that was only permitted for vehicles in funeral processions.*

- Public awareness campaigns should warn pedestrians against crossing a road or detour until not only the approaching vehicle has passed but any trailing dust cloud has dissipated.

*On a road project in Tanzania, two small children carefully waited for a project dump truck to pass by before crossing the unpaved road. They were struck and killed by a bus following the truck. The bus driver could not see the children and they could not see the bus through the dust cloud generated by the dump truck.*

## 4.5 SOCIAL IMPACTS OF ROAD CONSTRUCTION

Road construction projects typically provide both positive and negative social impacts during the construction phase. Positive social impacts may include a range of skilled and unskilled employment opportunities for the local population. Training and experience gained during the construction period can lead to long-term capacity enhancements for the local workforce. These enhancements include increased skills and earning potential for individual workers from on-the-job and formal training opportunities and the development or refinement of production techniques, supply chains, and marketing channels for local and national companies.

Road construction projects can result in temporary positive economic impacts from the procurement of goods and services (e.g., construction vehicles and machinery, construction materials, catering, laundry, food supply, security services). Temporary economic impacts will also stem from the induced economic effects of spending on goods and services by construction workers, who will have increased disposable income and the ability to spend more money in the local economy.

***Management and Mitigation Measures.*** Meaningful stakeholder engagement and collaboration with local stakeholders are key components in the assessment process when considering social impacts. Local input is required to gather information, feedback, local knowledge, local perspectives, and concerns; to identify opportunities for reducing social and economic impacts; to promote inclusion of marginalized, underrepresented, and vulnerable groups; to build greater social cohesion; and to ensure that the benefits of development are shared equitably across communities and civil society.

When consulting with Indigenous Peoples, the Policy on Promoting the Rights of Indigenous Peoples (PRO-IP policy) must be followed. The policy guards against harm by strengthening engagement, increasing the integration of Indigenous People's concerns across USAID's programming, and empowering Indigenous Peoples to advocate for and exercise their rights. Furthermore, Free, Prior, and informed Consent must be obtained, which is the concept that before a project may take place that would affect a person or community either positively or negatively, the person or community must give approval for the project to move forward (USAID 2020).

A formal GRM should be developed that provides a process for community members or other stakeholders to raise issues of concern regarding impacts from the road project. Community members should be advised how to file grievances or to raise any concerns about project impacts. Complaints should be recorded and responded to in accordance with the established GRM.

Some common negative social impacts and mitigation measures from road construction are described in the subsections below. Because social impacts are highly dependent upon the local circumstances, the listed impacts are only illustrative and not exhaustive, reinforcing the need for meaningful stakeholder engagement.

### 4.5.1 SITING CONSIDERATIONS

Decisions related to siting a road in a specific location can have negative social impacts related to environmental justice, cultural heritage, and sites of historical significance.

Environmental justice[11] includes the protection of marginalized and underrepresented groups that may experience increased vulnerability due to environmental harms caused by a project and may include (but are not limited to) Indigenous Peoples, LGBTQI+ individuals, persons with disabilities, children and other youth, older persons, women, low-income populations, and all disadvantaged and marginalized communities regardless of race, color, gender, or national origin. In the past, roads were often located through poor or marginalized communities because the lower land values reduced the land acquisition costs for the road. However, such road placement sometimes displaced or divided the community, causing a loss of social cohesion. USAID road projects must consider disproportionate impacts on marginalized and underrepresented groups when determining road location alternatives.

Because the construction of a road can disturb or destroy important elements of a community's cultural heritage, it is important to engage early on with stakeholders through consultations to become aware of cultural resources that may exist on or near the project site.

Cultural heritage includes tangible features such as monuments (e.g., architecture, sculptures, elements, or structures of an archaeological nature), groups of buildings, and sites (e.g., archaeological sites, burial sites, and areas of human-made and natural features) that are of outstanding universal value from a historical, artistic, scientific, aesthetic, ethnological, or anthropological point of view. Tangible examples of cultural heritage also include moveable objects (e.g., artifacts, paintings, coins, manuscripts, sculptures), underwater resources or sites (e.g., shipwrecks, ruins, submerged landscapes), and even paleontological remains.

Cultural heritage also includes intangible resources of cultural, historic, or traditional relevance that may not be immediately obvious to people not of that culture. UNESCO states that intangible heritage can include oral traditions and expressions, folklore, beliefs, language, knowledge, performing arts, social practices, rituals, festive events, and traditional craftsmanship (UNESCO 2003) (International Council on Monuments and Sites (ICOMOS) 2018).

> *In Tanzania, the baobab tree is culturally and spiritually significant.*
>
> *The ESIA for a U.S.-funded road project in Tanzania included a mitigation measure that required a goat sacrifice ceremony if a baobab tree needed to be cut down.*

***Management and Mitigation Measures.*** Road siting decisions should consider adjusting the alignment to avoid areas of cultural or historical significance (Figure 42). Similar considerations should guide decisions on the locations for borrow pits, quarries, camps, offices, and other road project components. Furthermore, a Chance Find Procedure (CFP) may be needed for road projects. A CFP is a proactive procedure that details what will happen in the event of a discovery of cultural heritage resources. The CFP should be complementary to the initial identification of cultural heritage efforts, which may include various noninvasive techniques such as surveys and remote sensing.

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[11] The foundations of environmental justice considerations and regulations in the United States are largely based on Executive Order 12898 from 1994, which was designed to focus the attention of federal agencies on human health and environmental conditions in minority communities and low-income communities and required federal agencies to adopt strategies to address environmental justice concerns within the context of agency operations. This preliminary policy framework was expanded on by Executive Order 14008 in 2021, which places the climate crisis at the forefront of foreign policy and national security planning and establishes goals aimed at prioritizing benefits environmental justice communities.

*Figure 42. Road Alignment Shifted Left to Protect Graveyard*

#### 4.5.2 COMPULSORY DISPLACEMENT AND RESETTLEMENT

Road construction often requires procurement of privately owned land. While governments, developers, and residents can sometimes come to an agreement involving the voluntary sale of such land, governments often exercise their right to compulsory acquisition of property for capital improvement projects. USAID guidelines and international best practices for compulsory displacement and resettlement (CDR) include mitigation measures that often go beyond the legal requirements governing the acquisition of land under eminent domain regulations (USAID 2016b).

In certain societies, some individuals, families, or groups may have land tenure that derives from traditional laws and customs, but which is not based on formal land rights and land titles in their names. Whereas private landowners with formal land rights and titles may receive compensation by law, those occupying and using land under customary or informal tenure may not be formally or legally recognized as entitled to compensation. (USAID 2023b), (USAID 2023c)

Improperly managed CDR can lead to far-reaching negative effects, including economic loss; homelessness; landlessness; impoverishment of marginalized, underrepresented, or vulnerable groups; degradation of the social fabric of a community; and psychological trauma. CDR is to be avoided, limited, or mitigated. Displacement involves not only the physical displacement that occurs when people must relocate homes or businesses to clear land for the road project but also the economic displacement that may occur when a business moves from a valuable location, a worker must travel a greater distance to get to his or her place of employment, or an individual or business loses access to natural resources that provided an economic or survival benefit. Displacement can also have social implications by disrupting or dispersing communities, fracturing social networks, or reducing access to cultural resources or important heritage sites. Resettlement to alternative sites can have negative social impacts on both the resettled population and the established community at the new site, with one or both groups subject to discrimination, prejudice, social conflicts, or violence.

Failing to address resettlement impacts satisfactorily can adversely affect the lives and well-being of the individuals and the communities who will be displaced. This can be particularly devastating for marginalized, underrepresented, or vulnerable individuals or groups. Some Indigenous Peoples are particularly vulnerable to social and economic hardships resulting from displacement and resettlement due to their distinct spiritual and cultural relationships with their land and resources.

Displacements need not be permanent to justify compensation. For example, although a renter may not own the property, he or she may still face economic losses due to working time lost while looking for new accommodations and due to moving expenses (USAID 2016b).

***Management and Mitigation Measures.*** When there is the potential for partial or total physical displacement, economic displacement, or resettlement, the social impacts must be assessed and addressed in the ESIA. Furthermore, USAID's Environmental Compliance Procedures (22 CFR 216) identify resettlement as a class of action with a "significant effect" on the environment and therefore require, as appropriate, an Environmental Assessment (EA) or Environmental Impact Statement (EIS).

An important first step is to review the Agency's social assessment resources, including the Environmental Compliance Factsheet: Stakeholder Engagement in the Environmental and Social Impact Assessment Process (USAID 2016a).

*The goal is always to leave the affected legitimate landholders in a better position than before the displacement and resettlement (USAID 2016b).*

USAID has implemented guidelines that cover compulsory displacement and resettlement (CDR) (USAID 2016b) that results from USAID programs. Specific guidelines that USAID and its partners should follow to avoid, minimize, and mitigate CDR risks include the following:

- Understand the legal and institutional contexts;
- Identify all legitimate landholders and relevant risks;
- If physical displacement is unavoidable, develop a Resettlement Action Plan (RAP);[12]
- Promote informed and meaningful engagement;
- Improve livelihoods and living standards; and
- Provide additional protections to marginalized, underrepresented, and vulnerable groups, especially women and Indigenous Peoples.

The USAID CDR guidelines are consistent with leading international standards on land and resource tenure, including International Finance Corporation (IFC) Performance Standard 5, Land Acquisition, and Environmental and Social Standard 5 (ESS5) in the World Bank Environmental and Social Framework (World Bank 2018). Resettlement policies must consider not only the impacts on the displaced people, but also the impacts on the communities to which the displaced people are resettled. Failure to address the issues of all stakeholders can lead to social resentment, community conflicts, or violence.

Land tenure issues can be complicated in areas that may not have a formal system of land ownership or of documentation of land ownership. Traditional rights of use (e.g., for grazing animals or farming) may be allocated at the local level without a legal registration system. USAID must consider these alternate forms of land tenure and land use when assessing impacts, designing mitigation measures, and determining compensation.

#### 4.5.3 DISRUPTION OF LIVELIHOODS

The acquisition of land for road construction and physical disruptions during construction can have a variety of adverse economic impacts on the livelihoods of project affected people. Farmers may lose some or all of their acreage, employees may be forced to resettle farther from their workplace, and businesses may suffer a reduction in income if their customers are cut off or impeded from accessing shops or businesses. (World Bank 1997)

***Management and Mitigation Measures.*** The nature and range of economic impacts may not be immediately apparent during the planning phase, so community outreach and stakeholder engagement are necessary to discover the potential impacts. It is important that USAID or its Implementing Partners

[12] A Resettlement Action Plan is based on engagement with the affected legitimate landholders and sets forth how impacts from physical displacement will be addressed and ensures that any resettlement occurs in conformity with USAID guidelines and international standards.

engage stakeholders early in the project life cycle. The potential for adverse impacts on community members' livelihoods needs to be addressed at the local level and often on an individual basis.

During site visits and siting studies, the impacts of the road alignment on businesses should be considered and discussed with those businesses. For example, siting a road too close to an existing restaurant may diminish the appeal and profitability of an outdoor café even if no direct land taking is involved.

During construction, traffic control measures and pedestrian pathways and crossings should, to the extent practicable, allow continued access to local businesses. If access must be restricted temporarily for safety reasons, compensation for the loss of sales may be appropriate. If adequate dust control measures are not maintained, frequent and persistent dust may cause customers to avoid the area, damage or reduce the marketability of goods in stores, or cause a business to incur greater cleaning costs. Some disruption of existing livelihoods may be offset by hiring the affected persons on the road project until the disruption from construction is over.

A Sustainable Livelihoods Approach may be useful when completing a social impact assessment for a project that may affect the rural poor (Serrat 2017) (van Rijn, Burger and den Belder 2012). A Livelihoods Restoration Strategy may be necessary to avoid adversely affecting stakeholders in areas where comparable economic opportunities are not readily available (World Bank 2009).

### 4.5.4 LAND OR WATER USE CONFLICTS

During construction, the increased population from the temporary project workforce may lead to increased use or exploitation of water and other natural resources either by the project staff or by the local population in support of the project staff. Resource exploitation may involve gathering or providing wood for heating or cooking; harvesting wood for charcoal production; increased timber cutting for project lumber; collecting non-wood forest products such as mushrooms, berries, or herbs; hunting wild animals for bush meat; or illegal trade in animal products.

***Management and Mitigation Measures.*** The road project employment conditions should set strict guidelines prohibiting any illegal poaching or collection of plants, wood, or wild animals (bush meat) with meaningful consequences for violation, such as termination of employment. Any wood or charcoal used by the project or by project personnel should come from sustainable sources. If firewood is needed, any trees cut during land clearing for the road could be cut, split, and seasoned for future use.

In areas where water is scarce, project water demands may compete with existing local uses. The project should only use water sources that do not reduce water availability below the level required to support existing water needs. If increased demand leads to an increase in the cost of water, the project should bear the costs by developing independent water sources, transporting water to the project area, or compensating users for the additional costs.

### 4.5.5 LABOR INFLUX

A road construction project may cause a temporary labor influx to provide the unskilled and skilled labor needed to carry out the civil works. Impacts from the labor influx may be more pronounced in sparsely populated areas and in small communities where the size of the project workforce is a significant percentage of the baseline population. The labor influx, albeit temporary, may cause social and economic stresses on local housing markets and increase competition for and the prices of goods and services.

In addition to direct project personnel, a large labor influx may induce an influx of "followers" who seek an economic benefit from the temporary workforce and their disposable income. The followers may include merchants, service providers, and sex workers. Competition between the followers and established local merchants and service providers can lead to conflicts. Makeshift structures or temporary business operations set up by followers may not adhere to best environmental practices and lead to sanitation or waste management issues.

***Management and Mitigation Measures.*** If the road project establishes a construction camp for the non-local workforce, many of the potential impacts of the project labor influx can be more easily managed, including those related to housing, water supply, sanitation, and fuel for heating and cooking. Controlling access to the construction camp to project personnel reduces issues related to vendors and sex workers in the camps. Establishing a controlled area near the entrance of the camp can prevent the creation of an uncontrolled market just outside the camp gates.

Impacts from an influx of external labor can be minimized by tapping into the local workforce, which may involve training to develop the required skills. Training and hiring local personnel can increase public acceptance of or support for the project.

Establishing a worker code of conduct can be an effective mechanism to reduce the incidence of fighting, substance abuse, theft, or harassment of local residents by project personnel and establish standards for discipline or termination of any employees who participate in such actions. Establishing good relationships and open communication among community leaders, law enforcement personnel, and project leaders can help in the early identification of problem areas or behaviors and foster community cooperation. The World Bank guidance note on Managing the Risks of Adverse Impacts on Communities from Temporary Project Induced Labor Influx (World Bank 2016) provides additional strategies for managing the impacts from labor influx.

#### 4.5.6 GENDER CONSIDERATIONS

Many social impacts are gender differentiated, and they can affect men and women in different ways. Men and women have different traditional household and community roles in almost all societies (Lahiri-Dutt and Ahmad 2011). USAID supports gender equality with the goals of improving the lives of people by advancing gender equality; empowering women and girls to participate fully in, and equally benefit from, the development of their societies on the same basis as men; and securing equal economic, social, cultural, civil, and political rights regardless of gender. USAID policy requires that gender analysis "be integrated in strategic planning, project design and approval, procurement processes, and measurement and evaluation" (USAID 2012).

Because USAID considers women to be a vulnerable group, special attention must be paid to how a road construction project may affect women. Gender analysis "is a systematic analytical process used to identify, understand, and describe gender differences and the relevance of gender roles and power dynamics in a specific context. Such analysis typically involves examining the differential impact of development policies and programs on women and men and may include the collection of sex-disaggregated or gender-sensitive data. Gender analysis examines the different roles, rights, and opportunities of men and women and relations between them. It also identifies disparities, examines why such disparities exist, determines whether they are a potential impediment to achieving results, and looks at how they can be addressed" (USAID 2011).

Disparate gender impacts on road projects may involve imbalances in stakeholder input, decision making, employment opportunities, and monetary compensation for project impacts.

***Management and Mitigation Measures.*** Gender analysis for a road project should consider potential gender issues throughout the project planning and design, construction, and implementation phases, including the common gender issues discussed below (USAID 2021).

USAID road projects require stakeholder engagement and consultation as part of the process of identifying, avoiding, and mitigating adverse environmental and social impacts. In some cultures, it may not be acceptable or common for men and women to attend together or participate equally in a public forum. In these cases, the stakeholder outreach and consultations may need to be targeted toward each gender separately.

*Figure 43. Woman Employed as an Inspector*

The road project representatives presenting and soliciting information may need to be of a particular gender to maximize attendance and participation. Stakeholder engagement may need to be conducted in small groups rather than or in addition to larger public forums. Gender roles may limit the public participation of either men or women at certain times of the day. Public meeting communications should indicate whether childcare will be available on-site and whether babies and young children are allowed at the venue because exclusion may create a gender-biased barrier to public participation. In addition to public meetings, other methods of stakeholder engagement, such as key informant interviews, household surveys, or targeted focus groups, may be employed to reach a representative cross section of stakeholders.

Road projects present significant employment opportunities. Construction jobs tend to be disproportionately given to men, creating gender-imbalanced economic opportunities. Road projects require a wide variety of skills and abilities to perform jobs as manual laborers, skilled tradespeople, office workers, human resources specialists, engineers, accountants, supervisors, equipment operators, mechanics, traffic management personnel, inspectors, maintenance staff, food workers, security guards, and more. USAID road projects should endeavor to make employment opportunities available to all potential workers.

Construction workers moving into an area can create additional social pressures related to gender. Groups of workers away from home for long periods of time often seek out social activities in the area where they are temporarily based, not uncommonly involving potential sexual partners. These activities may involve both informal interactions with local residents and commercial transactions with professional sex workers. The transient nature of the workforce may create increased risks of sexual harassment, gender-based violence, or sex trafficking.

*Figure 44. Woman Employed as a Flagperson*

When monetary payments are made to a household as compensation for physical or economic displacement, the payment must be made in a manner that benefits the displaced persons. Consultation with all stakeholders can help discover potential pitfalls or benefits to alternative payment methods. As an example, on one project, the project social impact team worked with local banks to help set up household accounts to avoid the need to make disbursements in cash that might be more likely to be spent on goods or services that would not benefit the family.

# 5 ENVIRONMENTAL AND SOCIAL IMPACTS AND MITIGATION MEASURES – ROAD OPERATION

Impacts of new and upgraded roads continue long after the construction or rehabilitation phase has been completed due to the existence and active use of the road throughout its operation phase. This section presents typical impacts and common mitigation measures of road operation, categorized as ecological, traffic safety, social, developmental, and maintenance issues. Many aspects of road operation have multiple, cross-cutting impacts.

Although USAID's ability to mitigate impacts during road operation are limited, some of the operational adverse impacts may become apparent prior to handover of the road, i.e., when USAID still has an active oversight role and potentially some financial leverage. The project GRM can be used by community members or other stakeholders to raise issues of concern regarding emergent operational impacts. In particular, noise, dust, and traffic safety issues may arise as the road nears completion.

## 5.1 DEFORESTATION AND LOSS OF VEGETATION

Even when road siting considers and construction environmental controls minimize deforestation and vegetation loss, there may still be some impacts on forests, grasslands, and other natural areas due to future development induced by the road.

Many landscapes once dominated by old-growth forests are rapidly disappearing or surviving in old-growth mosaics, fragmented by alternate land uses due to the construction of roads. New road construction can spawn networks of additional secondary and tertiary roads, often due to illegal land colonization (Laurance, Sloan, et al. 2015), leading to further deforestation and habitat fragmentation.

New or improved roads increase the ease of access to any nearby forested areas. The improved access increases the risk of illegal or unsustainable extraction of forest resources, such as timber or charcoal, and can lead to additional deforestation.

***Management and Mitigation Measures.*** Management of future development near new or improved roads may be best managed by legal mechanisms or government planning to prevent or limit development in or near forests, wetlands, or other sensitive habitats. Regulations prohibiting or restricting the conversion of forest areas to agricultural uses can protect forests but may face backlash from large agricultural interests, small independent farmers, and populations that are food insecure.

## 5.2 ROAD ECOLOGY

Transport networks—in this instance, roads—are critical elements of human economic development and society, and global rates of network construction will likely rise for the foreseeable future (Laurance and Arrea 2017). Growing concern about these ecological road effects has led to the emergence of a new scientific discipline called "road ecology." The goal of road ecology is to provide planners with scientific advice on how to avoid, minimize, or mitigate negative environmental impacts of transportation (Balkenhol and Waits 2009). It is the study of the ecological effects (both positive and negative) of roads and traffic and has been in use since the 1980s (Forman and Alexander, Roads and their major ecological effects 1998) but is perceived to be under-researched in many developing countries (Collinson, Davies-Mostert, et al. 2019).

Roads are continually being constructed to facilitate effective transport of goods and services and to improve access to resources and employment opportunities. However, budgets allocated for building, upgrading, and maintaining roads rarely mention offsets for the indirect and direct effects of roads or their cumulative effects on biodiversity (Laurance and Arrea 2017). Therefore, there is a perennial conflict between development and biodiversity objectives, often on a global scale, and innovative strategies are required to minimize the ecological impact of roads, as well as to improve people's livelihoods (Collinson, Davies-Mostert, et al. 2019).

Road ecology encompasses studying the complex relationships between roadways and the natural systems they bisect (Forman 1998). Accurate quantification and effective mitigation of road impacts rely on scientifically robust research and monitoring. The earliest road ecology studies reported rates of wildlife-vehicle conflict (i.e., a collision resulting in a roadkill; see (Stoner 1925)), which is possibly one of the most visible ecological impacts of roads and traffic. As road networks expanded and traffic volumes increased, research began to focus on quantifying and reducing roadkill rates, particularly for large herbivores. In the past two decades, attention has expanded to include smaller species and encompass a wide range of biological and ecological parameters, such as species distribution and abundance, behavior, dispersal, and population dynamics such as genetics (Collinson, Davies-Mostert, et al. 2019), (Pinto, Clevenger and Grilo 2020). Road ecology is also concerned with changes in access to and the availability of natural resources. Natural resource development poses risks to biodiversity and can include land use changes, potential second growth habitat that converges with that of the primary habitat, and the loss of species. These risks are at the expense of providing people access to previously unobtainable resources (Wilkie, et al. 2000).

Transportation has numerous diverse—and mostly negative—consequences for biodiversity and ecosystem function. The effects of roads on the biotic and abiotic components of the ecosystems through which they pass are usually indiscriminate (Coffin 2007), and their influence may be both subtle and profound. Mammals and birds are arguably the most studied class of animals in road ecology (D'Amico, et al. 2015), and the negative impacts of roads on these two taxonomic groups are the same as those for others—habitat loss, road mortality, barrier effects, and habitat degradation through light, noise, and chemical pollution. Studies on the impacts of roads on mammals and birds date back to the 1970s, and these decades of research have provided opportunities to both explore and develop the theoretical road ecology space (Forman and Alexander, Roads and their major ecological effects 1998). In contrast, reptile- and amphibian-specific studies, as well as studies of aquatic species (i.e., fish), emerged over the past two decades and were generally species specific (as opposed to taxonomic) and spatially localized (Ruediger 2001), (D'Amico, et al. 2015). Literature for all taxonomic groups (both terrestrial and aquatic) has progressed from identifying and exploring impacts (such as road mortalities) to testing and evaluating mitigation strategies. In the past decade, researchers also reflected on study design and analyses, identifying common pitfalls and strengths (Collinson, et al. 2015).

Road ecology addresses the following concerns:

- Behavioral responses, which may induce animals to pause or speed up when crossing a road or to avoid the road altogether;
- Wildlife-vehicle collisions, which commonly result in the injury or death of individuals trying to cross the road corridor (D'Amico, et al. 2015), (Santos, et al. 2017);
- Barrier effects, which involve individuals who are unable to cross the road, either through low/high traffic volumes (Figure 45), physical barriers such as roadside fences, or unfavorable and/or isolated habitat patches on both sides of the road corridor (Rytwinski and Fahrig 2015), (Barrientos, et al. 2019));
- Disturbance due to traffic noise, light, pollution, and vibration, which implies a loss of quality of the adjacent habitat, if not a total lack of use of it by wildlife (Parris 2015);
- Habitat loss, reduction, fragmentation, or disturbance (Rytwinski and Fahrig 2015), (Barrientos, et al. 2019)), which, when associated with the previous impacts, decrease the amount of favorable habitat available, potentially impact the connectivity of migratory routes, or render habitat unsuitable for several species, resulting in species loss;
- Spread of invasive species through the road corridor, which is facilitated because the road right-of-way is usually homogeneous along long stretches of the corridor, allowing the expansion of invasive species, which are often transported—directly or indirectly—with road construction materials or via vehicles (Ascensão and Capinha 2017); and

These concerns are discussed below, except for changes in access to and availability of natural resources which is covered in Section 5.5.

### 5.2.1 BEHAVIORAL RESPONSES

Animals exhibit several general types of behavior around roads. Some species avoid crossing the road or will cross only when traffic volumes are low. This response can fragment animal ranges and have major impacts on gene pools through decreased access to a mate, thus threatening population survival. Other species modify their crossing behavior and either pause in the road when traffic approaches or speed up to flee from danger (not always with success). Still other species exhibit no apparent response to oncoming traffic and continue to cross, often to their demise. Figure 45 outlines the impacts from these behavioral responses, with some species examples (modified from (Forman and Alexander, Roads and their major ecological effects 1998)).

| Wildlife Behavioral Responses and Impacts | Species Examples |
|---|---|
| **Avoiders -** These species will only cross when traffic volumes are low. These species experience the lowest mortality rates but may suffer from population fragmentation depending on how often traffic volumes are low. |  Carnivores, Domestic Dogs, African Elephants |
| **Pausers -** These species detect the danger oncoming traffic poses to them but respond by stopping (or by continuing to scavenge). The longer they stop or pause, the greater the risk of them being hit by the oncoming vehicle. High traffic volume presents a complete barrier to these species. |  Amphibians, Chameleons, Owls, Tortoises, Snakes |
| **Speeders -** These species flee from danger but may flee directly into an oncoming vehicle. Shy species may be at risk from a barrier effect and population fragmentation. |  Antelope, Guineafowl, Rabbits/Hares, Rodents |
| **Non-Responders -** These animals fail to detect or take avoidance behavior with regard to oncoming vehicles and will continue to try to cross the road. The likelihood of a successful crossing decreases with an increase in traffic. These species are vulnerable to population reductions and fragmentation effects. |  Amphibians, Invertebrates, Livestock, Snakes |

Figure 45. Wildlife Behavioral Responses to Roads and Traffic

### 5.2.2 WILDLIFE-VEHICLE CONFLICTS

While the disruption of animal behavior around roads is equally important, wildlife-vehicle conflicts or collisions (often called “roadkill”) are the most direct and evident impact due to their visual nature and have the longest history in the literature. Stoner provided one of the earliest records of roadkill in the United States (Stoner 1925). The collection of roadkill data by dedicated research teams can be extremely costly due to the high sampling effort required, while efforts to reduce wildlife mortality around main roads, particularly in developing countries (Collinson, Davies-Mostert, et al. 2019), are often hampered due to a lack of research, with other priorities usually dictated by the country’s socio-economic situation. This often limits the number of roadkill studies and yet these data are vital not only for implementing effective mitigation strategies (Collinson, et al. 2015) but also for understanding the cumulative impacts.

***Management and Mitigation Measures.*** The three basic mitigation approaches to reducing wildlife-vehicle conflicts are to separate animals from the road, change driver behavior, or change animal behavior (Huijser, et al. 2021).

Reducing the probability of a collision with an animal on the road can be done primarily through preventing the animal's access to the road by adopting the technical aspects of roadside fencing (Rytwinski and Fahrig 2015). When used in combination with measures such as reduced speed limits (particularly at fence ends), fencing can be effective in reducing roadkill numbers and is a common method used throughout the world. However, fencing often results in the fragmentation of natural habitats, acting as a barrier to movement and impacting migratory patterns and range, further isolating wildlife populations, constraining the movement of animals, and preventing access to adjacent habitats (van der Ree, et al. 2011).

Adapting adjacent roadside infrastructure can partially prevent wildlife from being trapped between the fence and the road by using one-way gates and earthen ramps, which provide an escape route. However, consideration needs to be given to the trade-off between the risk of a species being killed on a road and whether fragmentation by fencing will increase population isolation (Huijser, Duffield, et al. 2009).

Modifications to driver behavior can include road closures, typically from dusk to dawn, when nocturnal species are most active (Laurance, Goosem and Laurance 2009), and traffic-calming measures such as reduced speeds, speed bumps, "aggressive" curves, and narrower lanes (Huijser, Duffield, et al. 2009), combined with wildlife signage. While the latter is generally considered ineffective (when used in isolation) for reducing roadkill (Huijser, Duffield, et al. 2009) due to motorist habituation if they operate continuously (Lehnert and Bissonette 1997), signage is most effective when employed with other measures such as crossing structures.

Wildlife behavior can be modified with the use of repellants, noise makers, and unattractive roadside vegetation.

No single method of preventing wildlife road conflicts has proven to be entirely effective under all circumstances. From an ecological perspective, mitigation that promotes habitat connectivity is always preferred to an option that prevents natural movement. A review of more than 20 mitigation measures that are used to reduce wildlife-vehicle conflicts found that very few were highly effective and most did not promote habitat connectivity (Huijser, et al. 2021).

#### 5.2.3 BARRIER EFFECTS

Roads that act as barriers to terrestrial, semi-aquatic, or aquatic wildlife movement fragment populations and habitats. They can also limit wildlife migration and dispersal through restricting the connectivity of habitats (Rytwinski and Fahrig 2015) and genetic interchange (Proctor, et al. 2012), ultimately threatening population viability (especially in combination with collision mortality). The degree of the barrier effect caused by roads varies by species, road type, and traffic (van der Ree, et al. 2011).

Usually persistent over time, the acoustic environment is also impacted by road traffic. Whilst this may be mitigated through natural or manmade sound barriers, road noise not only contributes to the barrier effect but creates stress for animals and makes it harder for animals to hear one another, their predators, and their prey (Parris 2016).

***Management and Mitigation Measures.*** Maintaining connectivity between populations on opposite sides of the road allows animals to access resources and mates and facilitates gene flow, thereby improving the viability of wildlife populations. Wildlife and fish passage structures are the most visible and engineering-intensive measures employed to address wildlife needs along roads and are the cornerstone of successful strategies to minimize transportation impacts. Examples of such structures are canopy bridges, wildlife tunnels and overpasses, fish ladders, and fish-friendly culverts. They have proven to be highly effective in promoting passage for a variety of wildlife species (Ruediger 2001), (Rytwinski and Fahrig 2015) and, combined with wildlife fencing, have dramatically reduced the incidence of roadkill (Clevenger, Chruszcz and Gunson 2001), (Lesbarrères and Fahrig 2012), (Huijser, Fairbank, et al. 2016). In contrast, underpasses facilitate animal and fish passage under a road. Crossing structures for other purposes, such as water flow or the movement of livestock or vehicles, can be modified to also allow the movement of wildlife (Rytwinski and Fahrig 2015). Large overpasses have also been designed to facilitate wildlife passage across roads, even across multilane highways, such as U.S. 101 in California and Interstate 80 in Nevada (ARC Solutions 2012), (Sahagún 2021). These passage structures can vary greatly in price, scope, and size and their design should be supported by wildlife studies. Monitoring programs can be established to evaluate the efficacy of wildlife and fish passage structures to adaptively improve them and to refine criteria for the placement of future structures.

Topographical features, surrounding landscape (which may be at higher or lower elevations), and vegetative characteristics effectively create natural barriers and channel wildlife movement that can extend for hundreds of meters on either side of the road (Kroll 2015). While these might also function as sound barriers and protect animals and their acoustic environment, maintaining ecological corridors through the creation of permeable access points for road crossings is essential for allowing animal movement and connectivity (Jaeger 2015).

### 5.2.4 DISTURBANCES DUE TO TRAFFIC NOISE, LIGHT, VIBRATION, AND CHEMICAL POLLUTION

Less visible physical factors related to roads and their associated users, such as traffic noise, light, vibration, and chemical pollution, can have far-reaching effects and cascading consequences, with communities and key species being altered (Reijnen, et al. 1995). Many of these factors typically arise within the "road-effect zone," the extent of which can vary considerably based on the level of traffic volume and road type. The effects can impact animal response anywhere from 10 to hundreds of meters from a road (Forman, Sperling, et al. 2003). These factors reduce adjacent habitat occupancy and foster avoidance behaviors (McClure, et al. 2013).

In addition, contaminants from vehicles can leave harmful deposits in the soil, water, surrounding habitat, and air, the main consequence of which is the deterioration of habitat quality for many plant and animal species (Forman, Sperling, et al. 2003), (D'Amico, et al. 2016). Leakage of gasoline, diesel fuel, motor oil, or hydraulic fluids from poorly maintained vehicles or vehicles damaged in crashes can lead to pollution of nearby water sources. Similarly, nearly imperceptible drips of oil from numerous vehicles can leave a residue on paved surfaces that washes off, leaving an oily sheen when it rains. This effect may be more pronounced where heavy vehicles have difficulty climbing steep hills.

***Management and Mitigation Measures.*** Adapting the roadside vegetation and infrastructure can minimize light spillage and reduce the visibility of human activities. Suggestions for reducing road noise levels, which have been known to alter certain species' mating calls, include making quieter road surfaces, motors, tires, and vehicle aerodynamics. Reducing pollution dispersal can be partially addressed by using cleaner fuels (Collinson and Patterson-Abrolat 2016).

Bridge deck runoff control measures, such as conveyance systems or spill capture storage tanks and vaults, can be used to prevent potentially harmful runoff and accidental spills from entering water bodies below. Stormwater management controls, such as swales, detention basins, bioretention measures, and sand filters along roadways and near waterways, can reduce potential pollution impacts from road operations.

### 5.2.5 HABITAT DISTURBANCE, REDUCTION, FRAGMENTATION, LOSS, OR CHANGES IN LAND USE

Populations of terrestrial and aquatic species need to be connected, which is a central priority for their conservation. However, land use, land cover, and connectivity within the landscape may change or lower the quality of the remaining habitat due to expanding road networks (Perz, et al. 2008). A road may cause habitat destruction, disturbance, loss, or fragmentation (Benítez-López, Alkemade and Verweij 2010), which may strongly reduce species' dispersal among resource patches and hence influence migratory patterns and range, population distribution, and persistence, as well as impact genetic diversity (Kindlmann and Burel 2008).

These habitat impacts can extend anywhere from a meter to a kilometer away from the edge of the road. The management of roadway verges often creates an "edge" in what used to be continuous habitat. Depending on the ecosystem type, this edge effect can decrease the density of species that are sensitive to edge habitat (especially forest interior species) and that may be less likely to survive due to competition with exotic species, edge predators, and overall poor habitat quality (Laurance, Nascimento, et al. 2007).

In addition to direct habitat loss, roads also cause indirect impacts. For example, species may no longer occupy otherwise sufficient habitat that is adjacent to roads because of behavioral responses to roads. Different activity patterns of predators and prey have been observed in roadside habitats. While some predators may frequent the zone closest to the road, many prey species avoid the area, thus impacting the food chain. There are limited studies to verify this, and more research is needed to understand the processes driving the detected patterns (Ruiz-Capillas, Mata and Malo 2013). Conversely, predator avoidance of roads can attract prey species to the relatively safer habitat (Berger 2007).

***Management and Mitigation Measures.*** Construction of new roads should be avoided if the roads would interrupt species migration corridors or would fragment contiguous habitat into disconnected parcels, if the interruption of fragmentation would have significant adverse impacts on the terrestrial or aquatic species. Public access to private secondary roads (e.g., logging roads) should be reduced or prevented wherever possible (Laurance and Arrea, Roads to riches or ruin? 2017).

Creating "natural" roadsides, which are the key linkages between the road and the surrounding land, could provide an enormous amount of new habitat, potentially increasing wildlife populations far more than any loss to roadkill (Forman 2010). More importantly, roadside vegetation in the road verge can narrow the opening created by a road, thus improving habitat connectivity and increasing the probability of successful wildlife movement across roads (Goosem, Izumi and Turton 2001).

Narrow roads create lower average vehicle speeds. This can be simulated by painting the lanes narrower, giving the impression of a narrower road. Reduced driver speeds give animals and motorists more time to react, thereby reducing wildlife-vehicle collisions.

### 5.2.6 SPREAD OF INVASIVE SPECIES THROUGH ROADS AND PREDATOR TRAPS

Road verges, or roadsides, are characterized as the zones adjacent to the road that are generally modified and distinctly different from the adjacent natural habitat, which is often separated by fencing. They serve as micro-habitats known to contain a high abundance of small mammals, seed-eating birds, reptiles, and invertebrates, particularly in wide verges (Meunier, Verheyden and Jouventin 2000). Roads can provide corridors for non-native species invasion, particularly on roadside verges. Invasive spread of plant species is often initiated by motor vehicles or road construction materials, which act as dispersal vectors (Kleinschroth, et al. 2016). Introduced exotic or non-indigenous flora and fauna may severely destabilize and outcompete local plant and animal communities.

Road verges support intensively managed habitats, which are artificially created on bare soil after road construction and subsequently experience frequent mowing (Le Viol, et al. 2008). This has direct consequences on both the wildlife and the plant communities they support. Artificial landscaping and frequently mowed grass may alter the natural characteristics, attract wildlife, or serve as predator traps,[13] increasing the rate of wildlife-vehicle collisions (Milton, et al. 2015). Studies have documented the introduction and persistence of exotic plants (Hansen and Clevenger 2005) and invasive animal species (D'Amico, et al. 2015) along roadsides.

***Management and Mitigation Measures.*** There is a need to identify and promote biodiversity-friendly construction and management practices in order to optimize the role of road verges as refuge for native flora and fauna. Roadside verges can be designed and maintained as pollinator habitat and corridors (Hopwood, Black and Fleury 2015), (Phillips, et al. 2020). Currently, there is limited awareness or concern that roads might act as vectors for the dispersal of alien and invasive plant species, and a greater understanding of the extent and impact on native species is required (O'Farrell and Milton 2006). To better mitigate the spread of alien and invasive plant species, perennial vegetation cover and ongoing management of roadside vegetation are required to control the continuous spread of weeds. Artificial

[13] A predator trap is an area that attracts predators but leads to their death.

landscaping should be discouraged and plants native to the region should be utilized for roadside soil stabilization (Steinfeld, et al. 2007).

## 5.3 TRAFFIC SAFETY

Approximately 1.3 million people are killed and between 20 million and 50 million are injured annually in road traffic accidents. More than half of the fatalities are pedestrians, cyclists, and motorcyclists, with 93 percent of the world's traffic fatalities occurring on roads in low- and middle-income countries. Road traffic injuries are the leading cause of death for children and young adults ages 5 to 29 (WHO 2021).

The causes of many of these accidents include unsafe road infrastructure; driving under the influence of alcohol or drugs; poor driving skills; failure to use protective equipment, such as motorcycle helmets, seat belts, and child restraints; violation of traffic laws, especially speeding; unsafe vehicles; distracted driving; inadequate enforcement of traffic laws; and lack of traffic safety communication to drivers and other road users.

***Management and Mitigation Measures.*** The prevalence of road traffic injuries can be reduced through careful design of road safety features, proper maintenance and operation of vehicles, driver and public education, and enforcement of traffic laws.

Engineered road safety features include geometric standards for adequate sight lines, road grades, curve radii and banking, and lane width; the determination of safe maximum speeds; adequate signage and traffic controls; proper surface traction; traffic-calming measures such as road narrowing, meanders, and speed bumps in populated areas; and protection of non-vehicle road users with properly designed footpaths, bicycle lanes, and safe crossing points. Road crossing design and operation should consider the safe crossing requirements of disabled, senior, and injured citizens, who may need more time than others to cross a road and should consider pedestrian safety at dawn and dusk. In some areas, signage and other warning devices for livestock crossings may be required. Effective maintenance of these safety features is an important component of safety strategies.

Other important mitigation measures include improving vehicle safety features, improving post-crash care for victims of road crashes, and setting and enforcing laws related to key risks. Safe road use behavior can be encouraged through the promotion of driver knowledge and understanding of traffic rules and situations; the improvement of driving skills through training and experience; and strengthening or changing driver attitudes toward risk awareness, personal safety, and the safety of other road users.

Public communication and education campaigns aimed at non-drivers can be important tools for improving road safety. A new or upgraded road is apt to result in more motor vehicles on the road and increased vehicular speeds, posing new and unfamiliar risks to pedestrians and cyclists. An education program in the schools near these roads can alert students to the increased dangers from higher traffic volume, faster vehicle approach speeds, and shorter crossing windows and teach students to face oncoming traffic when walking on the shoulders, to cross only in designated areas, and to habitually look both ways before crossing.

## 5.4 SOCIAL IMPACTS

The development of new roads, or the rehabilitation of existing ones, often improves personal livelihoods and may help reduce poverty in rural areas (Gachassin, Najman and Raballand 2010). Access to educational opportunities and social services, including health care, is often a key rationale for road improvements. New roads and road improvements may increase connectivity to important transportation hubs, such as the national road network, ports, and airports, as well as the development potential of an otherwise isolated location.

However, socio-cultural values may be altered and the stability of communities may be adversely affected by exposure to social change. New road access can change how a place is used or valued.

### 5.4.1 IN-MIGRATION

Road rehabilitation or the completion of a new road may attract in-migration to an area. People may expect to find new employment or livelihood opportunities, such as farming. Improved transportation may attract traders, suppliers, and other service providers, especially to local communities where there may be limited resources and capacity to provide supplies and services. Increased access may also bring an influx of criminals or sex workers.

***Mitigation and Management Measures.*** Screening and scoping of adverse social impacts from in-migration should be included in the ESIA. The ESIA, which will include stakeholder engagement, must contain a social baseline to better understand the impact of in-migration on the community and will be necessary to evaluate and monitor the socio-economic and demographic changes experienced by the community due to in-migration.

### 5.4.2 INCREASED INTERCONNECTIVITY

A new or improved road may increase interconnectivity with other geographical areas. Some positive impacts may include better access to basic services, places of employment, and educational facilities. This new interconnection may also lend itself to a multitude of negative social consequences from illegal trafficking of drugs, humans, or wildlife. The enormous worldwide illegal market for drugs often leads to the formation of organized crime groups that use violence to protect their trade (Keefer, Loayza and Soares 2008). Human trafficking involves sexual exploitation and forced labor (Makisaka 2009). Wildlife trafficking is extremely harmful to ecosystems because it involves the poaching of endangered species for products such as meat, shells, and pelts (U.S. Department of Interior 2008).

Road improvements increase interactions among populations. New roads and improved roads serve as entry points for new products and services but also raise the specter of unwanted influences as communities become more open and accessible. These undesirable influences may include exposure to communicable diseases such as HIV/AIDS; unwanted social patterns such as increased alcohol or drug consumption; criminal activity such as robbery, drug trafficking, or kidnapping; and, in conflict areas, intrusion by official military or opposition forces.

Road improvements may also increase disputes over limited natural resources such as water and land, which may, in turn, lead to social violence or increased crime rates.

***Mitigation and Management Measures.*** It is crucial to understand the local context through a social impact assessment that includes meaningful engagement with and feedback from local communities. Special attention must be given to conflict dynamics to avoid, limit, or mitigate any adverse project impacts that may exacerbate existing local tensions. The social assessment may draw on the expertise of USAID's Bureau for Conflict Prevention and Stabilization (USAID 2023d) in particularly socially sensitive areas around the world. USAID has developed tools and resources to help undertake a more comprehensive conflict analysis, including technical publications on conflict management and mitigation (USAID 2023e).

### 5.4.3 DECLINE IN SCENIC VALUE

A new road or an improved road with increased width or increased traffic may be perceived to adversely affect scenic vistas, especially in relatively undeveloped areas. In addition to aesthetic changes, impairment of scenic views may decrease tourism and lower tourism revenues. Cumulative visual changes associated with the extension of pole-mounted utilities, additional land development, and reduction in natural habitat can amplify the alteration of scenic views.

***Mitigation and Management Measures.*** Protection of scenic values can be achieved by careful planning, early and effective engagement of community stakeholders to identify and preserve visually or culturally important views, consideration of visual impacts in design, and the maintenance of visual impact mitigation measures. The impacts of roads on viewsheds (scenic landscapes) can be minimized by integrating the road into the topography and landscape in the least intrusive manner possible, installing utilities underground, and adding vegetation or other landscaping features to lessen the visual impacts.

### 5.4.4 AIR EMISSIONS

Vehicles generate air emissions of combustion byproducts, although the concentrations emitted by well-maintained modern engines are not apt to present noticeable, local, public health, or nuisance impacts. Older or poorly maintained engines can produce orders of magnitude greater concentrations of noxious combustion byproducts, with the greatest health impact likely to be from PM2.5[14] particulate emissions from diesel trucks.

The physical motion of vehicle traffic can also generate particulate air pollution. On unpaved roads, the particulate matter will primarily be soil-based dust. Along paved roads with higher traffic volumes and speeds, the particulate matter will be a mix of soil-based dust resuspended from the road surface, some particles from wearing of the road surface and tires, and soil-based dust from adjacent areas made airborne from vehicle-created wind and turbulence. The suspended particulate matter, especially PM2.5, may cause respiratory issues in vulnerable groups, such as children, senior citizens, or people with underlying health conditions such as asthma.

The generation of dust also creates adverse visual impacts. Its subsequent deposition can be a nuisance, especially in residential areas. Frequent generation and deposition of dust can adversely impact sensitive habitats.

***Mitigation and Management Measures.*** Mitigation measures to minimize vehicle emissions and dust during road operation may involve limiting speed limits in ecologically sensitive or densely settled areas. In these areas, traffic management plans should endeavor to maintain a steady traffic flow at a reasonable speed, perhaps by instituting road narrowing or other traffic-calming measures.

Conditions that create traffic jams should be avoided because vehicles idling in traffic backups produce unnecessary combustion emissions. Vehicles making multiple starts and stops create more dust from the shear forces associated with increased braking and acceleration. Along a generally unpaved road, dust mitigation may include paving or some other improved wearing course to reduce dust generation on road segments in densely settled areas.

Rows of trees or other dense vegetation parallel to the road may be maintained along the road to act as dust barriers.

Community members may raise issues related to excessive dust during road operation through the project GRM.

### 5.4.5 NOISE

As a completed or improved road comes into use, there may be an increase in traffic noise that affects neighboring communities. Noise from increased traffic levels may cause health or psychosomatic issues in local populations, such as headaches, anxiety, or heightened irritability.

Therefore, it is important to consult with project-affected community members through stakeholder consultation and engagement to gain a better understanding of how noise and dust adversely affect them.

***Mitigation and Management Measures.*** Mitigation measures to minimize traffic noise during road operation may involve limiting speed limits in densely settled areas. Traffic management plans should endeavor to maintain a steady traffic flow at a reasonable speed, perhaps by instituting road narrowing or other traffic-calming measures. In areas with downhill grades, trucks could be prohibited from using compression braking, which can create disturbingly loud noises, but instituting and enforcing effective regulations at the local level can be difficult.

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[14] PM2.5 is fine particulate matter less than 2.5 microns (0.025 millimeter) in diameter. PM2.5 is an air pollutant that can be inhaled into the lungs and cause or exacerbate respiratory problems.

Sound-deflecting or sound-absorbing walls, earthen berms, rows of trees, or other dense vegetation parallel to the road may be included in the road design to act as noise barriers.

Community members may raise issues related to excessive noise during road operation through the project GRM.

#### 5.4.6 ZOONOTIC DISEASE TRANSMISSION

Rehabilitating "dormant" roads in remote areas or completing construction of new roads may introduce people to new locations that were undisturbed or not very accessible to humans. Expanded human activities or settlements may encroach upon previously remote wildlife habitats due to road development. These scenarios may bring about an increase in zoonotic disease transmission, wherein humans and wildlife come into contact with each other and transmit disease.

***Mitigation and Management Measures.*** Development of this type of penetration road building would normally require an EA or EIS per 22 CFR 216.2(d)(1)(viii). The scoping statement for the EA or EIS should consider reasonably foreseeable human-wildlife interactions during road operation, including the potential transmission of zoonotic diseases. Although this is an operational impact, mitigation may include avoiding or minimizing such interactions by design changes that reroute the road away from areas of greatest risk. The wildlife baseline study and the social baseline study can facilitate future monitoring efforts to measure any increase in disease prevalence or the emergence of new diseases.

### 5.5 INCREASED ACCESS TO PROTECTED AREAS OR NATURAL RESOURCES

Mobility and accessibility are of primary importance to people, who generally welcome more roads. Increasing a road network increases accessibility for drivers, often into remote areas where the increased access rapidly degrades the previously remote habitat and leads to habitat reduction or loss (Forman 2010). Forest removal for building new roads represents an extreme example of vegetation removal, often associated with logging practices, particularly in the Central African rainforests (Laurance, Goosem and Laurance 2009). Other examples include opening new roads for expanded agricultural development, which puts adjacent forests at risk, especially where no effective forest management systems are in place. The environmentally most "dangerous" roads are those that penetrate into relatively pristine regions, such as protected areas. An example of this includes the proposed Serengeti Highway in Serengeti National Park, Tanzania, which could disrupt one of the world's largest wildlife migrations (Gadd 2015).

Once a road is in place, it provides access to people wanting to supply urban markets with wood products, such as charcoal, fuelwood, bush meat, or construction materials, contributing further to deforestation, carbon emissions, and a loss of carbon sinks. Roads may create new and welcome opportunities for income generation but may lead to conflicts over resource extraction or overexploitation of resources.

Roads may provide new transportation routes to areas that were previously inaccessible, which can lead to increased levels of hunting and fishing (either legal or illegal) in those areas. Increased hunting and fishing may lead to unsustainable depletion of animal populations and may deplete the food supply of local communities, thus posing a threat to species that local communities may rely on for their sustenance or livelihoods (Government of Pakistan 2012). Access provided by new roads can contribute to poaching and the trapping of endangered species or trafficking in wildlife species with international trade value. Increased access to previously unattainable resources has been shown to lead to an increase in poaching in Africa (Wilkie, et al. 2000), (Laurance and Arrea, Roads to riches or ruin? 2017).

***Management and Mitigation Measures.*** Because new roads provide communities access to previously unattainable resources, engaging with local communities to seek alternate options to fuelwood (e.g., solar panels for stoves and heating water) may limit human disturbance. Training forestry patrols may prevent illegal harvesting of bushmeat or wildlife poaching.

Given the environmentally transformative roles of roads, particularly when it comes to protected area management, a global zoning exercise can be undertaken to identify areas that should remain road-free.

USAID interprets parks and protected areas to include all six International Union for the Conservation of Nature (IUCN) categories for parks and protected areas, including Strict Nature Reserve/Wilderness Area, National Parks, National Monument or Feature, Habitat-Specific Management Areas, Protected Landscape/Seascape, and Protected Areas with Sustainable Use of Natural Resources. If a proposed road alignment is inside or near a park or protected area, then the following safeguards[15] must be met (USAID 2023f):

1. Establish, communicate, and maintain appropriate grievance and redress mechanisms.
2. Consider the impact of the road project on affected communities, with a particular focus on land and resource claims related to the park or protected area.
3. Consult local communities regarding the road project and its potential impacts, rising to free, prior and informed consent consistent with the USAID Policy on Promoting the Rights of Indigenous Peoples (USAID 2020).
4. Train and monitor rangers and similar personnel regarding safe and fair application of the law, including respect for human rights and avoiding intimidation or unnecessary use of force, in the context of the USAID-funded road project.
5. Establish, communicate, and maintain an appropriate implementer-led grievance and redress mechanism for reporting human rights abuses, misconduct, and other grievances.

## 5.6 DEVELOPMENT AND LAND USE CHANGES

Common induced development pressures and land use changes that occur because of a new or improved road include agricultural expansion, residential development, and commercial and manufacturing businesses. Development and land use changes depend on national, regional, and local laws and regulations; zoning and building codes; and urban and rural development plans. The absence or lack of enforcement of such laws, regulations, codes, and plans can also affect the type, scale, and speed of induced development.

The development and land use change may cause short- and medium-term direct and indirect impacts, but the long-term cumulative impacts of development typically have the greatest consequences.

Agricultural development tends to increase significantly when new roads expand into previously inaccessible areas or when existing roads are improved. The improved access lowers transportation costs and, importantly for farmers, decreases transportation time and product damage when bringing produce to market. Increased agriculture can lead to deforestation and the conversion of natural habitats to farmland, as well as to secondary impacts such as increased water use, erosion of topsoil, siltation of surface water bodies, and contamination from fertilizer or pesticide use.

Agricultural expansion and developments such as gas stations, restaurants, bars, hotels, markets, retail stores, and residential housing are largely irreversible. Residential, commercial, and manufacturing development implies increased energy use, water use, waste generation, and pollution. The increased population from the road-induced development often creates additional pressure for further development.

***Management and Mitigation Measures.*** Increased development in desirable areas is generally considered to be a beneficial outcome of road development; however, adverse impacts can arise if developers reap the benefits without bearing the external costs, including the environmental costs. These costs include protecting natural habitats, water, topsoil, and other natural resources from pollution, degradation, and unsustainable rates of exploitation. Management techniques may include zoning and land development regulations, permitting processes, fees for extending or using sanitation infrastructure or waste management facilities, and enforcement for violations. Long-term planning can

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[15] The details of the required safeguards and the USAID-funded activities to which they apply depend on the year of funding. See (USAID 2023f) for current requirements.

help a community or region develop in a predictable manner and can help infrastructure development keep pace with population growth and community needs.

The EA or EIS for a road project should consider the types of likely development and the growth potential over a reasonably foreseeable time horizon so that the regulators who approve the road project understand the additional investment that will be needed to support sustainable development. The baseline information in the EA or EIS will provide important information to help monitor and evaluate future growth and the effectiveness of any associated mitigation measures.

### 5.7 MAINTENANCE

Poorly designed or inadequately maintained unpaved roads contribute to soil erosion through the development of multiple wheel tracks as travelers try to avoid standing water and ruts from previous traffic. The development of multiple tracks can occur wherever inadequate attention is paid to keeping standing water off the road surface. Rutting effects may be particularly pronounced where roads pass through silty or clayey soils. The presence of water, fine-grained soils, and the mechanical forces of tires loosens the soil and fosters soil erosion.

Inadequate maintenance of a road not only impedes travel along the road but can also cause impacts as drivers attempt to avoid damaged parts of the road. Drivers' attempts to avoid potholes, deep wheel ruts, or flooding in the official roadway often leads to travel on the road shoulder or adjacent natural ground.

Landscaped road rights-of-way often support intensively managed habitats, which are artificially created on bare soil after road construction and subsequently experience frequent mowing (Le Viol, et al. 2008). This has direct consequences on both wildlife and plant communities due to the reinforcement of edge effects and the possible introduction or promotion of vegetation distinct from that on bordering land.

***Management and Mitigation Measures.*** Regular and proper maintenance of the road surface and drainage system will minimize pavement failure, rutting, and drivers deviating from the road surface. Wet-season traffic on roads designed only for dry-season use can severely damage the road surface and promote erosion. Closure and enforcement are the recommended management measures; however, they can provoke off-road driving. The best solution, if there is a significant demand during rainy seasons, is to upgrade the road for wet use.

Biodiversity-friendly maintenance and management practices should be identified and promoted to optimize the role of road verges as a refuge for flora and fauna. The selection of vegetation for areas adjacent to the road should be compatible with the surrounding area.

Maintenance responsibilities should be discussed with local governments or communities early in the planning process and before the final design of the road because the type and level of affordable and realizable maintenance will be factors in the design choices. A road maintenance agreement should be developed prior to construction. All parties must clearly understand and be committed to the terms of the agreement, such as who will do what work, when, how frequently, for what compensation, and within what limits. A long-term funding source for the road maintenance should be determined.

Considerations for the maintenance program include developing a regular schedule of maintenance, routine inspection of the road, record keeping on the road condition and maintenance activities, and an adequate budget. If motorized equipment is required for maintenance, the equipment should be properly sized for the required use. The equipment must be maintainable in the locale of the road and consider the cost, the supply chain for spare parts and consumables, the availability of trained mechanics, and the availability of operators or the ability to train them. In some areas and for some road types, manual labor may be a less expensive and more sustainable approach to road maintenance. A road maintenance program can provide employment opportunities, enhance skills, improve the local economy, and build local technical capacity.

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