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THE LAW OF ENHANCED WEATHERING FOR CARBON DIOXIDE REMOVAL

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EXECUTIVE SUMMARY

Despite scientists' dire warnings about the catastrophic impacts of climate change, the greenhouse gases that cause it continue to be emitted in substantial amounts. While there is no question that deep, across the board cuts in greenhouse gas emissions are essential, many scientists now agree that simply cutting future emissions will not be enough. It will also be necessary to remove previously-emitted greenhouse gases from the atmosphere. This paper explores one greenhouse gas removal technique—enhanced weathering—which involves spreading finely ground silicate rocks or other materials with similar chemical composition over land or ocean waters. The materials react with carbon dioxide, sequestering it in mineral form (e.g., as limestone) on land or in the oceans. While further study is needed to fully evaluate the risks associated with enhanced weathering, initial research suggests that it could result in the long-term storage of large amounts of carbon dioxide, likely for centuries or millennia.

This paper examines the international and U.S. legal framework for enhanced weathering on land and in ocean waters. The paper identifies international and U.S. federal and state laws that could apply the performance of enhanced weathering projects. Laws applicable to the sourcing of materials for use in such projects are dealt with in a separate (forthcoming) paper by the author.

There are currently no international or U.S. federal or state laws dealing specifically with enhanced weathering, but projects could be regulated under various general environmental and other laws. At the international level, potentially applicable instruments include the Convention on Biological Diversity, Convention on the Prevention of Marine Pollution by Dumping of Waste and Other Matter, and the United Nations Convention on the Law of the Sea. Domestically, projects could be subject to various provisions of the Clean Water Act, Clean Air Act, Resource Conservation and Recovery Act, and Marine Protection, Research, and Sanctuaries Act, among other statutes. Exactly when and how these statutes will apply remains uncertain. Much will depend on the specific design of each project, including where it is conducted, the materials used, and how they are applied to land or ocean waters. The paper identifies areas where new laws could be adopted, or existing laws revised, to reduce uncertainty and facilitate the development of enhanced weathering projects.

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ACRONYMS

BLM	Bureau of Land Management
BUD	Beneficial Use Determination
CAA	Clean Air Act
CBD	Convention on Biological Diversity
CCR	Coal Combustion Residuals
CWA	Clean Water Act
EEZ	Exclusive Economic Zone
EIS	Environmental Impact Statement
EPA	Environmental Protection Agency
ESA	Endangered Species Act
FIP	Federal Implementation Plan
FLPMA	Federal Land Policy Management and Act
FWS	Fish and Wildlife Service
IPCC	Intergovernmental Panel on Climate Change
MPRSA	Marine Protection, Research, and Sanctuaries Act
NAAQS	National Ambient Air Quality Standards
NEPA	National Environmental Policy Act
n.m.	Nautical mile
NFMA	National Forest Management Act
NPDES	National Pollutant Discharge Elimination System
NYDEC	New York Department of Environmental Conservation
OCS	Outer Continental Shelf
PM2.5	Particulate matter consisting of particles with diameters of 2.5 microns or less
PM10	Particulate matter consisting of particles with diameters of 10 microns or less
RCRA	Resource Conservation and Recovery Act
RMP	Resource Management Plan
SIP	State Implementation Plan
UNCLOS	United Nations Convention on the Law of the Sea
U.S.	United States

1. INTRODUCTION

In the 2015 Paris Agreement, the international community set a goal of "[h]olding the increase in the global average temperature to well below 2°C above pre-industrial levels," and committed to "pursuing efforts to limit the temperature increase to 1.5°C."[1] A growing body of scientific literature has since demonstrated the essentiality of remaining within the 1.5°C threshold. Most notably, a 2018 report by the Intergovernmental Panel on Climate Change ("IPCC") found that temperature increases exceeding 1.5°C above pre-industrial levels would lead to catastrophic heat waves, droughts, floods, and other climate-induced changes.[2]

Limiting warming to 1.5°C above pre-industrial levels will require the rapid elimination of greenhouse gas emissions. Due to past emissions, global average temperatures are already 1°C higher than pre-industrial levels, and the carbon budget consistent with a 1.5°C threshold is expected to be breached within the next decade if emissions continue at current rates.[3] A 2019 United Nations Environment Program report found that, to stay within the 1.5°C threshold, global greenhouse gas emissions will need to decline by fifty-five percent by 2030 and reach "net zero" around mid-century.[4] That implies average global emissions reductions of over seven percent annually.[5] By comparison, during the last decade, annual global emissions have *increased* by 1.5 percent annually.[6]

In its 2018 report, the IPCC concluded that cutting greenhouse gas emissions will require "systems transitions [that] are unprecedented in terms of scale," with "far-reaching" changes needed across all sectors.[7] Even this may not be sufficient to limit warming to 1.5 or 2°C, however. Many scientists now agree that, as well as reducing future emissions, it will also be necessary to

[1] Paris Agreement, Dec. 12, 2015, Art. 2(1)(a).
[2] Myles Allen et al., *Summary for Policymakers in* GLOBAL WARMING OF 1.5OC: AN IPCC SPECIAL REPORT (V. Masson-Delmotte et al. eds, 2018).
[3] *Id*. at 12 (calculating a "remaining carbon budget of 580 [gigatons of carbon dioxide] for a 50% probability of limiting warming to 1.5°C, and 420 [gigatons] for a 66% probability" and finding that the budget "is being depleted by current emissions of 42" gigatons per year"). *See also* Joeri Rogelj et al., *Paris Agreement Climate Proposals Need a Boost to Keep Warming Well Below 2°C*, 534 NATURE 631, 635 (2017) (indicating that the "carbon budget" consistent with 1.5°C of warming could be exhausted by 2030); Jan C. Minx et al., *Negative Emissions—Part 1: Research Landscape and Synthesis*, 13:6 ENVTL. RES. LETTERS 063001, 3 (2018) (estimating that the carbon budget could be exhausted within five years).
[4] UNITED NATIONS ENVIRONMENT PROGRAM, EMISSIONS GAP REPORT 2019 XV (2019),https://perma.cc/4TYR-XKUW.
[5] *Id*. at XX.
[6] *Id*. at XIV.
[7] Allen et al., *supra* note 2, at 15.

remove previously-emitted greenhouse gases from the atmosphere. Indeed, all of the emissions pathways identified in the IPCC's 2018 report as consistent with limiting warming to 1.5°C assume use of greenhouse gas removal or negative emission processes.[8] Use of such processes is also required in most of the 2°C-consistent pathways identified by the IPCC in its Fifth Assessment Report on climate change.[9]

In broad terms, negative emission processes remove greenhouse gases from the atmosphere and store them in terrestrial biomass, underground geologic formations, the oceans, or the built environment, or utilize them in some fashion, such as for enhanced oil recovery (though the environmental impacts of this are contested) or in the manufacture of fuels or other products.[10] To date, most research has focused on removing and storing or utilizing carbon dioxide, which is the primary greenhouse gas emitted through human activities.[11]

Many carbon dioxide removal techniques are based on processes that already occur naturally as part of the earth's carbon cycle.[12] One example is enhanced weathering which aims to accelerate natural processes in which carbon dioxide reacts with silicate-rich rocks in the presence of water.[13] The reaction releases carbonate or bicarbonate ions, which either form carbonate minerals (e.g., limestone) on land or are washed into the oceans, where they eventually become carbonate sediments on the seafloor.[14] In the latter situation, the flow of ions into the oceans also increases the alkalinity of the water, enabling it to absorb more carbon dioxide from the atmosphere.[15]

Research shows that the natural weathering process can be enhanced by grinding silicate rocks to increase their surface area and then spreading them over land or ocean waters.[16] Several

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[8] *Id*. at 17.

[9] OTTMAR EDENHOFER ET AL., CLIMATE CHANGE 2014: MITIGATION OF CLIMATE CHANGE, CONTRIBUTION OF WORKING GROUP III TO THE FIFTH ASSESSMENT REPORT BY THE INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE 14-15 (2014), https://perma.cc/T8J5-MBTA.

[10] ROYAL SOCIETY & ROYAL ACADEMY OF ENGINEERING, GREENHOUSE GAS REMOVAL 8 (2018), https://perma.cc/NK4D-JXR4.

[11] *Id*.

[12] NATIONAL ACADEMIES, CLIMATE INTERVENTION: CARBON DIOXIDE REMOVAL AND RELIABLE SEQUESTRATION 3 (2015), https://perma.cc/LXF4-VN23.

[13] Royal Society, *supra* note 10, at 49.

[14] *Id*.

[15] *Id*.

[16] *See generally*, Jens Hartman et al., *Enhanced Chemical Weathering as a Geoengineering Strategy to Reduce Atmospheric Carbon Dioxide, Supply Nutrients, and Mitigate Ocean Acidification*, 51 REV. GEOPHYSICS 113, 117 (2013);

researchers have proposed applying ground rock to agricultural land, where it would not only sequester carbon, but also act as a fertilizer, improving soil health and simulating plant growth.[17] Ground rock could also be applied to other types of land or waters, such as forests and wetlands.[18] Additionally, enhanced weathering could be performed using non-rock materials, such as silicate-rich industrial and other wastes.[19] Further study is, however, needed to evaluate the risks associated with using different materials in different locations. [20]

The carbon dioxide captured through enhanced weathering is thought to remain sequestered for centuries or millennia.[21] There are, however, currently no established protocols for verifying the amount of carbon dioxide stored through enhanced weathering and the longevity of the storage. Such protocols will be needed if enhanced weathering projects are to be used to generate carbon credits or similar instruments for sale (e.g., under an emissions trading scheme). The ability to generate credits could help to incentivize investment in enhanced weathering projects, which are likely to be costly and may yield few or no other financial benefits (i.e., apart from possible increases in agricultural productivity). However, even with incentives in place, investment may be hindered by uncertainty regarding the legal framework for enhanced weathering.

There are currently no international or U.S. federal or state laws dealing specifically with enhanced weathering on land or at sea. Various general environmental and other laws could, however, apply to land- and sea-based enhanced weathering projects. This paper provides the first comprehensive analysis of potentially applicable laws.[22] As we shall see, because the laws were not developed with enhanced weathering in mind, there is often significant uncertainty as to whether, when, and how they will apply. Much will depend on the specifics of each enhanced weathering

[17] *See e.g.*, Fatima Haque et al., *Optimizing Inorganic Carbon Sequestration and Crop Yields With Wollastonite Soil Amendment in Microplot Study*, 11 FRONTIERS PLANT SCI. 1012 (2020); Fatima Haque et al., *CO2 Sequestration by Wollastonite-Amended Agricultural Soils – An Ontario Field Study*, 97 INTL. J. GREENHOUSE GAS CONTROL 103017 (2020); David J. Beerling et al., *Farming with Crops and Rocks to Address Global Climate, Food and Soil Security*, 4 NATURE PLANTS 138, 139 (2018); Jessica Strefler et al., *Potential and Costs of Carbon Dioxide Removal by Enhanced Weathering of Rocks*, 13 ENVTL. RES. LETTERS 030410 (2018).

[18] Hartman et al., *supra* note 16, at 11.

[19] *Id*.

[20] Royal Society, *supra* note 10, at 51.

[21] National Academies, *supra* note 12, at 3-4.

[22] The paper focuses on laws governing the conduct of enhanced weathering projects. It does not discuss legal issues related to the sourcing of materials for use in enhanced weathering. Those issues are the subject of a forthcoming paper by the author.

project, including exactly where it is performed, what materials are used, and how they are dispersed. The paper identifies areas where new laws or regulations could be adopted or existing ones amended to reduce uncertainty and facilitate the development of enhanced weathering projects.

The remainder of this paper is structured as follows: Part 2 begins with an introduction to enhanced weathering, how it is performed, and its benefits and drawbacks. Part 3 then explores legal issues associated with performing enhanced weathering on land in the U.S. under current law. Legal issues associated with enhanced weathering at sea, particularly in U.S. waters, are discussed in Part 4. Part 5 concludes.

2. ENHANCED WEATHERING: A PRIMER

2.1 What is Enhanced Weathering?

Enhanced weathering is one of several carbon dioxide removal strategies that aim to accelerate natural processes for removing carbon dioxide from the atmosphere and sequestering it on land or in the oceans. It is estimated that eighteen gigatonnes of carbon dioxide – i.e., equivalent to over half of annual global anthropogenic emissions – are removed from the atmosphere each year through natural processes.[23] One such process is mineral weathering whereby naturally occurring silicate rocks react with carbon dioxide in the presence of water.[24] The reaction releases carbonate or bicarbonate ions, which either remain on land and form carbonate minerals (e.g., limestone), or flow into the oceans and eventually become carbonate sediments on the seafloor.[25] In both cases, the process results in the long-term storage of carbon dioxide in mineral form, likely for centuries or millennia.[26] It may also lead to additional carbon dioxide being absorbed by, and stored in, ocean waters. The flow of ions into the oceans increases the alkalinity of the water, leading to the transfer

[23] National Academies, *supra* note 12, at 27 & 29.
[24] It is estimated that natural weathering of silicate rocks sequesters approximately one gigagtonne of carbon dioxide annually. *See* Nils Moosdorf et al., *Carbon Dioxide Efficiency of Terrestrial Enhanced Weathering*, 48 ENVTL. SCI. & TECH. 4809, 4809 (2014).
[25] Royal Society, *supra* note 10, at 49.
[26] *Id*. at 50. It should be noted that, while the carbon dioxide captured through weathering processes is thought to remain stored for centuries or millennia, there are currently no protocols for verifying the longevity of the storage.

of dissolved carbon dioxide to bicarbonate and carbonate ions, which enables the water to absorb more carbon dioxide from the atmosphere.[27]

The natural weathering process takes decades to centuries, but can be accelerated in various ways, including by increasing the surface area of reactive materials.[28] Enhanced weathering techniques seek to do just that by spreading finely ground silicate rocks or other suitable materials over land or ocean waters.[29] As in natural weathering processes, the materials react with carbon dioxide, and sequester it in the form of carbonate minerals. While the carbon dioxide is thought to remain sequestered for long periods, further study is needed to fully assess the potential for re-release back into the atmosphere.

To date, most enhanced weathering research has focused on the use of dunite, an igneous ultramafic rock that is comprised almost entirely of olivine, a fast-weathering magnesium iron silicate.[30] Due to its high silicate content, dunite has significant carbon sequestration potential, with up to 1.1 tons of carbon dioxide being sequestered per ton of dunite used.[31] Other ultramafic and mafic rocks can also be used, but yield lower sequestration rates, principally because they contain less silicate.[32] Two commonly discussed options are basalt and wollastonite, which are estimated to sequester up to 0.3 and 0.2 tons of carbon dioxide per ton of rock, respectively.[33] While this is significantly lower than dunite, the use of basalt or wollastonite may have other advantages, as discussed in Part 2.2 below.

There is also growing interest in using other materials for enhanced weathering. The most commonly discussed options are silicate-rich wastes, such as mine tailings generated as a by-product of hard rock mining, fly-ash left behind after the combustion of coal in electricity generating facilities, cement kiln dust extracted from the exhaust produced during cement production, and

[27] National Academies, *supra* note 12, at 47.
[28] Strefler et al., *supra* note 17, at 2.
[29] *See generally*, Hartman et al., *supra* note 16, at 117.
[30] Strefler et al., *supra* note 17, at 2.
[31] The theoretical upper limit for sequestration is 1.25 grams of carbon dioxide (0.34 grams of carbon) per gram of olivine. In practice, however, sequestration rates of between 0.8 and 1.1 tons of carbon dioxide (0.2176 to 0.2992 tons of carbon) per ton of olivine are more likely. The exact rate depends on several factors, including the size of the rock grains, and the climate in the area of application. *See id*.
[32] *Id*.
[33] Royal Society, *supra* note 10, at 49.

ferrous slag from iron and steel manufacturing.[34] (These and similar materials are referred to as "artificial silicates" in this paper.) Further research is needed to evaluate the benefits and drawbacks of using such materials.[35]

Whatever materials are used, they must be spread in a thin layer on land, or discharged into ocean waters. On land, the materials could be dispersed using fertilizer spreaders or similar equipment in areas accessible by road, or dropped from aircraft in roadless areas.[36] Periodically agitating the materials after they are applied to land—e.g., through tilling—can speed up the weathering process but this is not absolutely necessary. More important is choosing the right application site. To maximize carbon sequestration, materials should be applied to land in warm and humid climates (e.g., the tropics) that have deeply weathered soils, with limited supply of silicates.[37] In the U.S., such soils are principally found in the northwest, south, and southeast (see Figure 1 below).[38] The southeast is best suited in terms of climate, but other areas could also be used.[39]

As a practical matter, material application is likely to be easiest on agricultural land, where existing infrastructure (e.g., used to distribute and apply fertilizer) can be reused.[40] Croplands are thought to be ideal, not only because of the ease of applying materials but also because plant roots and associated microorganisms speed up the weathering process, while the accumulation of carbon in the soil enhances plant growth and further accelerates the process.[41] A 2018 study estimated that, using all suitable croplands[42] globally, up to 95 gigatons of carbon dioxide could be sequestered

[34] Hartmann et al., *supra* note 16, at 123.
[35] *See infra* Part 2.2.
[36] This paper does not consider issues associated with the licensing or other approval of vehicles used to apply materials (e.g., Federal Aviation Authority approvals for the use of aircraft).
[37] Hartmann et al., *supra* note 16, at 14.
[38] *Id.* at 15.
[39] Strefler et al., *supra* note 17, at 4.
[40] *Id*. Applying minerals to agricultural lands may also have other benefits, for example, in terms of increased crop yields. *See infra* Part 2.2.
[41] Royal Society, *supra* note 10, at 49. The potential for increased crop yields is discussed further in Part 2.2 *infra*.
[42] The study defined "suitable croplands" as those in warm or temperate climates. The study identified 5.1 x 10^6 square kilometers of suitable land in warm climates and 2.8 x 10^6 square kilometers of suitable land in temperate climates. *See* Strefler et al., *supra* note 17, at 4.

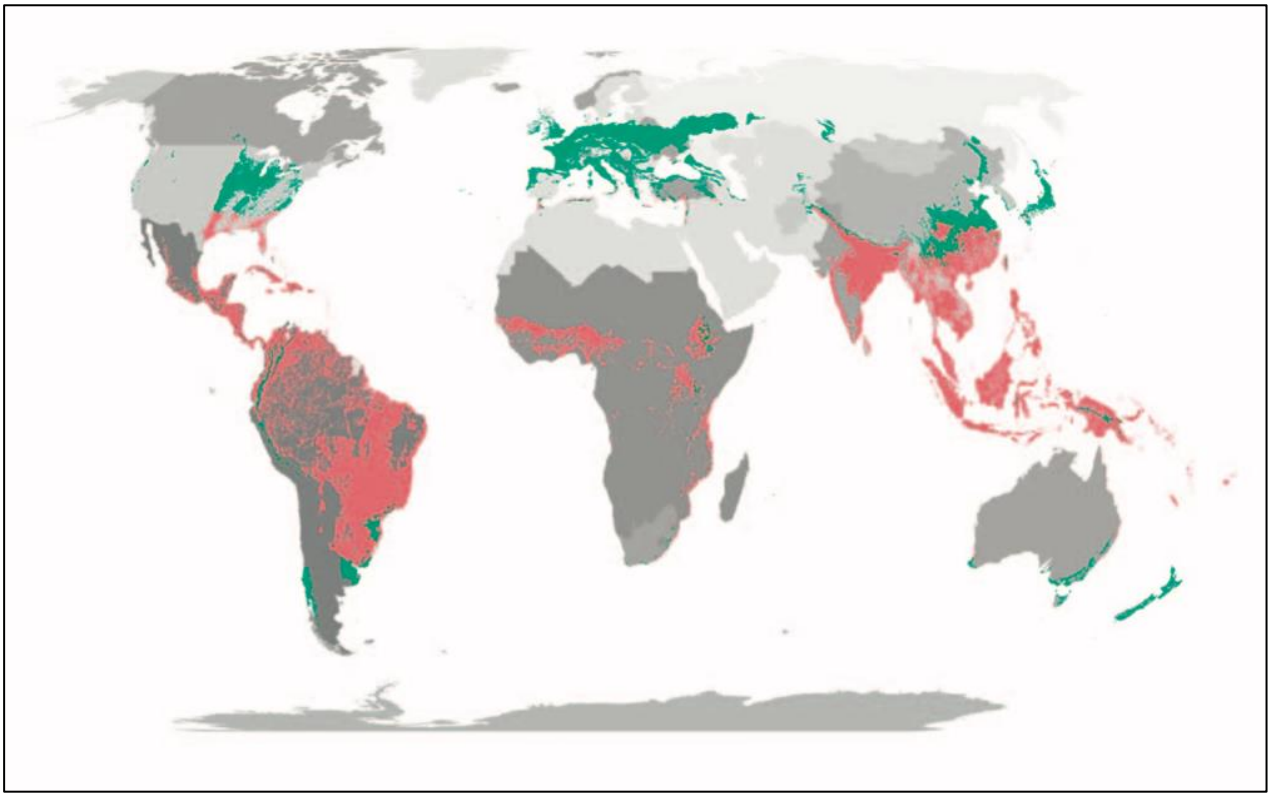

Figure 1: Croplands in warm (red) and temperate (green) humid climates.

annually.[43] To put that figure in perspective, global energy-related carbon dioxide emissions totaled approximately 33 gigatons in 2019, meaning that enhanced weathering on cropland could sequester almost three years-worth of emissions.[44] Croplands in the U.S., China, and India have been shown to have the highest carbon sequestration potential.[45] In the U.S., up to 0.8 gigatons of carbon dioxide could be sequestered annually by applying ground basalt to croplands, and even higher sequestration rates achieved using other rocks (e.g., dunite).[46]

The amount of carbon dioxide sequestered through enhanced weathering could be further increased by also applying reactive materials to non-agricultural land. Several studies have discussed the possibility of using forest land, but this would likely necessitate dropping reactive materials from above using aircraft, which substantially increases costs. Indeed, one study estimated

[43] Using other materials would result in smaller amounts of carbon dioxide being sequestered. For example, if basalt is used, just 4.9 gigatons of carbon dioxide would be sequestered annually. See *id*.
[44] Int'l Energy Agency, *Global CO2 Emissions in 2019*, https://perma.cc/NTL5-TJWZ (last updated Feb. 11, 2020).
[45] David J. Beerling et al., *Potential for Large-Scale CO_2 Removal via Enhanced Rock Weathering with Croplands*, 583 NATURE 242, 243 (2020).
[46] *Id*.

that applying ground dunite or basalt rock to forest land would be twice as expensive as applying the rock to cropland.[47]

Enhanced weathering can also be performed at sea,[48] by discharging finely ground silicate rock or other reactive materials into the water, either at the coastline or further offshore.[49] Initial research suggests that rates of carbon sequestration may be higher in coastal waters (compared to areas further offshore) because the tidal motion of the waters results in frequent agitation of the materials, leading to abrasion which creates new reactive surfaces and prevents the build-up of coatings that can limit or prevent weathering.[50] In both coastal waters and further offshore, the amount of carbon sequestered per ton of rock used is lower at sea than on land, but researchers describe the difference as "relatively small."[51] In theory, ground rock could be spread across the entire ocean surface, resulting in significant carbon sequestration. A 2013 study estimated that distributing olivine across the ocean surface could sequester approximately four gigatons of carbon dioxide annually.[52] As an added benefit, distributing olivine or other silicate rocks in the ocean would also increase the pH of surface waters, counteracting ocean acidification.[53]

2.2 Benefits and Drawbacks of Enhanced Weathering

The key benefit of enhanced weathering is its technical simplicity. The basic process for enhanced weathering – i.e., dispersing ground silicate rock or other similar materials on land or at sea – is already performed in other contexts. In the agricultural sector, for example, ground minerals and other substances are routinely applied to land in order to adjust soil pH levels, increase nutrient

[47] Strefler et al., *supra* note 17, at 2.
[48] Sea-based enhanced weathering is similar to ocean alkalinization (also known as ocean liming), which involves spreading an alkaline substance (e.g., lime) over seawaters. Ocean alkalinization is sometimes, though not always, classified as a type of enhanced mineralization. INSTITUTE FOR CARBON REMOVAL LAW AND POLICY, ENHANCED MINERALIZATION FACT SHEET 1 (2018), https://perma.cc/2MS5-KH6K .
[49] KERRYN BRENT ET AL., GOVERNANCE OF MARINE GEOENGINEERING SPECIAL REPORT 13 (2019), https://perma.cc/6WF9-XAPT.
[50] Jasper Griffioen, *Enhanced Weathering of Olivine in Seawater: The Efficiency as Revealed by Thermodynamic Scenario Analysis*, 575 SCI. TOTAL ENV'T 536, 537 (2017). *See also* Hartmann et al., *supra* note 29, at 116.
[51] Hartmann et al., *supra* note 16, at 122. Sea-based approaches are estimated to sequester up to 0.28 grams of carbon per gram of olivine. *See* Peter Köhler et al., *Geoengineering Impact of Ocean Dissolution of Olivine on Atmospheric CO2, Surface Ocean pH and Marine Biology*, 8 ENVIRON. RES. LETT. 014009 (2013). In comparison, enhanced weathering on land is estimated to sequester up to 0.3 grams of carbon per grams of olivine. *See* Strefler et al., *supra* note 17, at 030411.
[52] Köhler et al., *supra* note 51.
[53] *Id*.

supply, or for other purposes.[54] This is typically done using hand-held or vehicle-mounted spreaders, which could be repurposed for use in enhanced weathering. Because existing equipment can be used, the cost of enhanced weathering is lower on agricultural land than in other areas. Even on agricultural land, however, enhanced weathering is among the more expensive carbon dioxide removal techniques.[55] Enhanced weathering on cropland is estimated to cost $60 per ton of carbon dioxide sequestered where dunite is used, $80 to $200 where basalt is used, and $240 where wollastonite is used.[56] All of these figures are well above recent estimates for afforestation ($24 per ton), bioenergy with carbon capture and storage ($36 per ton), and some forms of direct air capture ($27 to $136 per ton).[57]

As well as being costly, enhanced weathering may also have other drawbacks, depending on the materials used. Most studies have proposed using silicate rocks, such as dunite, the mining of which could have significant negative impacts. The construction of new mines typically entails land clearing, which results in carbon dioxide emissions that could partially, or in some cases (e.g., where forests are cleared) entirely, offset the climate benefits of undertaking enhanced weathering. Land clearing could also have other, more localized environmental impacts, including on soils (e.g., by leading to increased erosion) and animals (e.g., by resulting in habitat fragmentation). Additional impacts are likely to occur during mine operation which can, among other things, disrupt animal behaviors (e.g., breeding) and alter predator-prey dynamics. Mine operation has, in the past, also been a major source of local soil and water contamination.

The processing and use of rock materials also presents risks. During grinding and application of the rock, particles could become airborne and may be inhaled by humans or animals.[58] In humans, inhalation of silica particles can cause inflammation in the lungs, which over time leads

[54] Moosdorf et al., *supra* note 24, at 4809.
[55] The majority of costs associated with enhanced weathering are related to the processing and transportation of silicate-rich materials for application to land. *See* Royal Society & Royal Academy of Engineering, *supra* note 10, at 51.
[56] Strefler et al., *supra* note 17, at 8; Beerling et al., *supra* note 45, at 243; Haque, *supra* note 17, at 10; *Potential for Large-Scale CO_2 Removal via Enhanced Rock Weathering with Croplands*, 583 NATURE 242 (2020).
[57] Strefler et al., *supra* note 17, at 8. Strefler et al. reported costs for direct air capture of $430 to $570 per ton, but recent estimates put the figures significantly lower. *See e.g.*, Brandon R. Sutherland, *Pricing CO2 Direct Air Capture*, 3 JOULE 1571, 1572 (2019).
[58] *Id*.

to permanent scarring, resulting in respiratory problems.[59] The risk of inhalation can, however, be reduced by mixing the particles with water to create a slurry.[60]

Rock particles applied to land, whether in a slurry or dry, would be washed into rivers, where they may increase turbidity and thus harm aquatic organisms.[61] Similar impacts could also occur where ground rock is applied directly to the oceans.[62] With both ocean- and land-based approaches, there is also a risk of water contamination from trace elements in the rock. This is likely to be a particular problem where dunite is used because the rock often contains high concentrations of heavy metals, such as nickel and chromium, which could be released during the weathering process and accumulate in water, soils, and ultimately the food chain.[63] Compared to dunite, basalt and wollastonite typically have lower metal concentrations, and thus pose fewer environmental risks.[64] In fact, applying ground basalt or wollastonite to land may actually have environmental benefits, improving soil quality and thus stimulating plant growth.[65] This would result in additional carbon dioxide being taken up and stored by plants, partially compensating for the lower weathering efficiency of basalt and wollastonite (i.e., compared to dunite and other higher-silicate rocks).[66]

As discussed in Part 2.1 above, enhanced weathering can also be performed using artificial materials, such as silicate-rich wastes. This could have a number of benefits, avoiding issues normally associated with disposal of the wastes, as well as the mining and processing of new silicate rocks. Further research is, however, needed to assess the risks associated with widespread use of waste materials for enhanced weathering. As noted in a 2018 study by the Royal Society and Royal Academy of Engineers, "[t]he chemical composition of waste materials (such as mine tailings or slags) and risks of toxicity have not been widely assessed."[67]

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[59] U.S. Dep't of Labor, *Silica Crystalline*, SAFETY AND HEALTH TOPICS, https://perma.cc/V6ZZ-FSFT (last visited Aug. 28. 2020).
[60] Strefler et al., *supra* note 17, at 5.
[61] Royal Society, *supra* note 10, at 51.
[62] Brent et al., *supra* note 49, at 14.
[63] Beerling et al., *supra* note 17, at 139.
[64] *Id*. at 140.
[65] *Id*. See also Haque et al., *supra* note 17.
[66] Strefler et al., *supra* note 17, at 2.
[67] Royal Society & Royal Academy of Engineering, *supra* note 10, at 51.

3. ENHANCED WEATHERING ON LAND

There are no international or U.S. laws dealing specifically with enhanced weathering on land. The practice is, however, covered by international guidelines dealing generally with "geoengineering."[68] The guidelines were adopted under auspices of the Convention on Biological Diversity ("CBD"), which aims to promote "the conservation of biological diversity, [and] the sustainable use of its components."[69] Concerned that geoengineering activities may adversely affect biological diversity, in 2010, the Conference of the Parties to the CBD adopted a non-binding decision recommending that countries avoid such activities.[70] The decision "invites Parties [to the CBD] and other Governments . . . to consider [specified] guidance . . . on ways to conserve, sustainably use and restore biodiversity and ecosystem services while contributing to climate change mitigation and adaptation."[71] The guidance includes a recommendation that countries:

> [e]nsure . . . in the absence of science based, global, transparent and effective control and regulatory mechanisms for geo-engineering, and in accordance with the precautionary approach and Article 14 of the Convention, that no climate-related geo-engineering activities that may affect biodiversity take place, until there is in place an adequate scientific basis on which to justify such activities and appropriate consideration of the associated risks for the environment and biodiversity and associated social, economic and cultural impacts, with the exception of small scale scientific research studies that could be conducted in a controlled setting . . . and only if they are justified by the need to gather specific scientific data and are subject to a thorough prior assessment of the potential impacts on the environment. (Internal citations omitted.)[72]

That guidance was reaffirmed by the Conference of the Parties to the CBD in 2012[73] and again in 2016.[74]

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[68] Convention on Biological Diversity, May 22, 1992 [hereinafter "CBD"]. The U.S. is not a party to the CBD.
[69] *Id*. Art 1.
[70] Report of the Conference of the Parties to the Convention on Biological Diversity on the Work of its Tenth Meeting, Decision X/33, Art. 8 (2010).
[71] *Id*.
[72] *Id*. Art 8(w).
[73] Report of the Conference of the Parties to the Convention on Biological Diversity on the Work of its Eleventh Meeting, Decision XI/20, Art 6-9 (2012).
[74] Report of the Conference of the Parties to the Convention on Biological Diversity on the Work of its Thirteen Meeting, Decision XIII, Art. 14 (2016).

The 2010 decision defined geoengineering to mean "any technologies that deliberately reduce solar insolation or increase carbon sequestration on a large scale that may affect biodiversity."[75] The Secretariat to the CBD subsequently determined, and the Conference of the Parties agreed, that geoengineering should be defined more broadly to include any "[d]eliberate intervention in the planetary environment of a nature and scale intended to counteract anthropogenic climate change and its impacts."[76] Enhanced weathering is one such intervention and thus would fall within the scope of the 2010 decision. The decision's impact on enhanced weathering projects is limited, however. As noted above, the decision is non-binding, and merely "invites" countries to "consider" the guidance therein.

The U.S. is not a party to the CBD. Neither the U.S. federal government nor any state has adopted laws prohibiting or even directly regulating enhanced weathering. However, depending on exactly where and how enhanced weathering is conducted, projects may be subject to various existing, general environmental and other regulatory programs. Key examples of potentially applicable regulatory programs are discussed in this Part. The primary focus is on potentially applicable federal regulatory programs. While there is some discussion of state and local regulations, a full fifty-state review of all potentially applicable provisions is beyond the scope of this paper.

3.1 Securing Access to Land for Enhanced Weathering Projects

Enhanced weathering projects will require large amounts of land where ground silicate rock or other reactive materials can be applied. As discussed in Part 2.1 above, there is significant interest in using agricultural land, due to both the ease of applying reactive materials and the co-benefits that application can have (e.g., in terms of stimulating crop growth). From a legal perspective, obtaining access to privately-owned agricultural or other land will generally be straight-forward, at least where the owner is willing to sell or lease the land or otherwise agrees to it being used for enhanced weathering. However, even if an owner agrees to an enhanced weathering project on his/her/its land, that project would still have to comply with any requirements imposed by

[75] *Id*. footnote 3.

[76] SECRETARIAT OF THE CONVENTION ON BIOLOGICAL DIVERSITY, CBD TECHNICAL SERIES NO. 66, GEOENGINEERING IN RELATION TO THE CONVENTION ON BIOLOGICAL DIVERSITY: TECHNICAL AND REGULATORY MATTERS 23 (2012), https://perma.cc/LFU6-5RAU; Report of the Conference of the Parties to the Convention on Biological Diversity on the Work of its Eleventh Meeting, Decision XI/20, Art 5 (2012).

applicable federal, state, and local laws (including the permitting requirements discussed in Part 3.2 below).

A number of states and localities have so-called "agricultural preservation laws" that aim to ensure the availability of land for agricultural use and thus restrict non-agricultural activities in designated areas. In Pennsylvania, for example, state legislation authorizes municipal governments to adopt zoning ordinances that include "provisions to promote and preserve prime agricultural land."[77] Pursuant to that authority, several municipalities in the state have established agricultural protection zones in which only agricultural activities are permitted by right, and other uses require special approval.[78] The permissibility of enhanced weathering projects in agricultural protection zones would need to be assessed on a case-by-case basis after reviewing the relevant municipal zoning ordinances. It may be possible to argue that enhanced weathering is an agricultural activity because the application of silicate materials to the land stimulates crop growth and is thus equivalent to traditional agricultural practices involving fertilizer application. At a minimum, enhanced weathering is consistent with agricultural use of the land and does not result in it becoming unavailable for crop growing and similar activities, which is what agricultural protection laws are intended to prevent.[79] The laws in some states expressly allow activities consistent with agricultural use on protected land. One example is the California Land Conservation Act, which authorizes city and county governments to enter into contracts with agricultural landowners, under which the owners agree to limit the use of their land in return for a reduction in their property taxes.[80] Under the Act, contracts must only "[p]rovide for the exclusion of [land] uses other than agricultur[e]," and "those compatible with agricultur[e]."[81] Other states and localities that want to encourage enhanced

[77] 53 PA. CONS. STAT. § 10603(b)(7). *See also id*. § 10107 (defining "prime agricultural land").
[78] For a discussion of relevant municipal laws, *see* PENNSYLVANIA LAND TRUST ASSOCIATION, AGRICULTURAL PROTECTION ZONING (2013), https://perma.cc/72XC-E9DE. *See also* ROBERT ANDREW BRANAN, ZONING LIMITATIONS AND OPPORTUNITIES FOR FARM ENTERPRISE DIVERSIFICATION: SEARCHING FOR NEW MEANING IN OLD DEFINITIONS (2004), https://perma.cc/5T39-JN5F
[79] In some areas, agricultural preservation laws have been relied upon to restrict renewable energy projects on agricultural land but, unlike those projects, enhanced weathering does not involve the construction of any new facilities or require the removal of any land from agricultural use. See e.g., PORTLAND, NY, LOCAL LAW NO. 2 OF 2019 (2019).
[80] CAL. GOV'T CODE § 51240 et seq.
[81] *Id*. § 51243.

weathering could provide a similar general exemption for activities compatible with agriculture or specifically exempt enhanced weathering projects.

State and local agricultural protection laws will not, of course, apply where non-agricultural land is used for enhanced weathering. However, a variety of other legal issues could arise from the use of non-agricultural land, particularly where it is under federal or state ownership. In such cases, enhanced weathering projects will generally need to be permitted or otherwise approved by the relevant government land manager, which can be a difficult and time-consuming process as discussed below.

3.1.1 Federal Land

The U.S. federal government owns approximately 640 million acres of land, at least some of which may be suitable for use in enhanced weathering.[82] With some limited exceptions, federally-owned land can only be used with the prior approval of the relevant, government land manager. Nearly seventy percent of all federally-owned land is managed by just two government agencies.[83] The Bureau of Land Management ("BLM"), a division of the U.S. Department of the Interior, manages approximately 244.4 million acres of federally-owned land ("public land"), located almost entirely in the eleven coterminous western states and Alaska.[84] The U.S. Department of Agriculture's Forest Service manages a further 192.2 million acres of federal land ("federal forest land"), again located mostly in the west, though there are also some large areas of federal forest land in the east and south.[85]

While BLM and the Forest Service operate pursuant to different statutory frameworks,[86] both are required to manage the lands under their control in accordance with the principle of "multiple use," which requires the land and its resources to be "utilized in the combination that will best meet the present and future needs of the American people," while avoiding "permanent impairment of

[82] CAROL HARDY VINCENT ET AL., CONGRESSIONAL RESEARCH SERVICE, FEDERAL LAND OWNERSHIP: OVERVIEW AND DATA 1 (2020), https://perma.cc/B35F-T74A.

[83] The remaining thirty percent of federal lands are managed by a variety of federal agencies, including the National Park Service and Fish and Wildlife Service within Department of the Interior, and the Department of Defense. *Id*.

[84] *Id*.

[85] *Id*.

[86] BLM manages public lands pursuant to the Federal Land Policy and Management Act. *See* 43 U.S.C. § 1701 et seq. Federal forest lands are managed under several states, including the Multiple-Use Sustained Yield Act and the National Forest Management Act. See 16 U.S.C. § 528; 16 U.S.C. § 1600.

the productivity of the land and the quality of the environment."[87] BLM and the Forest Service must also adhere to the principle of "sustained yield," ensuring the maintenance of "high-level . . . output of the various renewable resources" within the land.[88] Where consistent with those principles, BLM and the Forest Service may authorize third-parties to use public and federal forest lands, respectively. This Subpart discusses key issues relating to the use of public and federal forest lands for enhanced weathering.

(A) Obtaining Approval to Use Public Land

Enhanced weathering projects on public lands will generally need to be permitted by BLM under the Federal Land Policy and Management Act ("FLPMA").[89] Some enhanced weathering projects may, however, qualify as a "casual use" of public land that does not require a permit.[90] BLM regulations, issued pursuant to FLPMA, define "casual use" to mean "any short term non-commercial activity which does not cause appreciable damage or disturbance to the public lands, their resources or improvements."[91] BLM has offered little other guidance on what it considers a casual use, merely indicating that it will "make a judgement on the requirements in [each] particular case."[92] BLM could support enhanced weathering projects on public land by designating them a casual use of the land where the regulatory requirements are met. Many projects are likely to be short-term in nature, involving the application of reactive materials to land over the course of days or months, with no follow-up activities (e.g., tilling). Depending on how each project is conducted, the other requirements for casual use may also be met. For example, if aircraft were used to drop reactive materials over land with no "on-the-ground" activities, an enhanced weathering project

[87] 43 U.S.C. §§ 1702(c) & 1732(a); 16 U.S.C. §§ 529 & 531(a).
[88] 43 U.S.C. §§ 1702(h) & 1732(a); 16 U.S.C. §§ 529 & 531(b).
[89] 43 U.S.C. § 1701 et seq.
[90] 43 C.F.R. § 2920.1-1(d).
[91] *Id*. § 2920.0-5(k).
[92] *See* BUREAU OF LAND MGMT., OBTAINING A RIGHT-OF-WAY ON PUBLIC LANDS 2 (2018), https://perma.cc/8UBN-8QZT. BLM has identified "sampling, surveying, marking routes, collecting data . . . , and performing certain activities that do not cause any appreciable disturbance or damage to the public land, resources or improvements" as examples of casual uses of public land. *See id*. at 1-2.

would result in no land disturbance. Thus, provided the project was shown not to have other adverse environmental impacts[93] and non-commercial, it would qualify as a casual use of land.[94]

Enhanced weathering projects that do not qualify as casual uses of public land would need to be authorized by BLM. Under section 302(b) of FLPMA, BLM may authorize the use of public land for any activity that is "not specifically authorized under other laws or regulations, and not specifically forbidden."[95] The use of public land for enhanced weathering is neither authorized nor forbidden by law and, as such, could be authorized under section 302(b). Authorizations can take a number of forms, including:

- permits, which are issued for short-term land uses (not exceeding three years) that involve little or no land improvement, construction, or investment;
- leases, which are issued for longer-term land uses that involve substantial construction or land improvement, and the investment of large amounts of capital; and
- easements, which are issued for land uses that are compatible with other uses, occurring on nearby or adjacent land.[96]

Enhanced weathering projects could likely be authorized through permits as they do not require the construction of buildings or other land improvements. In some cases, enhanced weathering projects may qualify for "minimum impact permits," which are available for land uses that will not cause "appreciable damage or disturbance."[97] Minimum impact permits are issued through a simplified process[98] and typically do not require preparation of an environmental impact statement ("EIS") under the National Environmental Policy Act ("NEPA").[99]

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[93] There is currently some uncertainty as to the potential for enhanced weathering projects to cause environmental damage. This requires further study. *See supra* Part 2.2.

[94] The requirement that casual uses be non-commercial could exclude enhanced weathering projects that generate carbon credits or similar instruments for sale.

[95] 43 U.S.C. § 1732(b); 43 C.F.R. § 2920.1-1.

[96] 43 C.F.R. § 2920.1-1.

[97] 43 C.F.R. § 2920.2-2.

[98] Ordinarily, prior to issuing a permit, BLM must publish a "notice of realty action" indicating that a specific tract of land is available for a specific use. Such notice is, however, not required where BLM issues a minimum impact permit. See *id*.

[99] As noted above, under NEPA, an EIS is only required for actions that "significantly affect[] the quality of the human environment." Minimum impact permits can, by definition, only be used to authorize land uses that do not have such effects.

As well as being permitted, some enhanced weathering projects on public lands may also require other approvals from BLM. For example, where new roads or similar access ways are required for a project, rights-of-way would need to be obtained therefor. Under section 501 of FLPMA, BLM may grant rights-of-way for roads, trails, and other transportation systems.[100] Before granting a right-of-way, BLM may need to prepare an EIS under NEPA, and hold a public hearing if sufficient interest exists.[101]

All approved uses of public land must be consistent with Resource Management Plans ("RMPs"), which are issued by BLM to guide management of the land.[102] Each RMP identifies resource goals for the area covered by the plan and specifies management practices to achieve those goals.[103] The RMP also identifies tracts of land within the covered area that are suitable for use in various activities, such as energy development, agriculture, and recreation.[104] BLM takes the view that, for an activity to be consistent with the applicable RMP, it must occur in an area identified as suitable for that type of activity.[105] At the time of writing, no RMP dealt with enhanced weathering specifically, nor carbon sequestration generally. Thus, before any enhanced weathering project could occur on public land, the RMP(s) applicable to the project area would need to be amended.[106] BLM has previously indicated that it will consider RMP amendments for carbon sequestration on a case-by-case basis when and where sequestration projects are proposed.[107] BLM is likely to take a similar approach to amendments for enhanced weathering.

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[100] 43 U.S.C. § 1761.
[101] 43 C.F.R. § 2804.25.
[102] 43 U.S.C. §§ 1712 & 1732.
[103] *See generally*, Bureau of Land Management, *Planning 101*, PLANNING AND NEPA, https://www.blm.gov/programs/planning-and-nepa/planning-101 (last visited Aug. 28, 2020).
[104] *Id*.
[105] This is different from the position taken by the Forest Service, which considers projects to be consistent with the applicable land use plan if that plan specifically permits the activity, or is silent about it. See *infra* Part 3.1.1(B).
[106] *See generally*, U.S. DEPARTMENT OF THE INTERIOR, REPORT TO CONGRESS: FRAMEWORK FOR GEOLOGICAL CARBON SEQUESTRATION ON PUBLIC LANDS 10 (2009) (on file with author) (indicating that RMPs "form the basis for every action and approved use on the public lands . . . Where sequestration activities are proposed, plan amendments will be needed to identify the suitability of public lands within the planning area, analyze environmental impacts . . . and provide for public review and comment.")
[107] *Id*. See also 43 C.F.R. § 1610.5-5 (providing that a RMP may be amended where there is "a change in circumstances or a proposed action that may result in a change in the scope of resource uses").

Before amending a RMP, BLM must publish a notice in the Federal Register and appropriate local media, inviting public comments on the amendments.[108] BLM must also comply with various other procedural requirements. For example:

- BLM must conduct an environmental review as required under NEPA.[109] NEPA requires federal agencies to prepare an EIS for any action they undertake, authorize, or fund that "significantly affect[s] the quality of the human environment."[110] The EIS must include an assessment of the likely effect of the action and alternatives on natural, economic, social, and cultural resources.
- BLM must consult with the U.S. Fish and Wildlife Service ("FWS") as required under the Endangered Species Act ("ESA").[111] Consultation is required under section 7 of the ESA where a federal agency undertakes, funds, or authorizes an action that could "jeopardize the continued existence of any endangered or threatened species or result in the destruction or adverse modification of habitat of such species."[112]
- BLM must consult with the Governor of the state in whose territory the land covered by the RMP is located.[113] Consultation is intended to ensure that the RMP, as amended, will be consistent with any applicable state and local plans, policies, or programs.[114] If the state Governor identifies any inconsistencies, he/she may suggest changes to the amendments, which must be accepted by BLM if it determines that they "provide for a reasonable balance between the national interest and the State's interest."[115]

Due to the myriad of steps involved, RMP amendments can take several months or years to finalize. As such, to ensure enhanced weathering projects on public land can proceed in a timely manner, BLM may wish to begin the amendment process early (i.e., before any specific project is proposed).

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[108] 43 C.F.R. §§ 1610.2 & 1610.5-5.
[109] 42 U.S.C. § 4321 et seq.
[110] *Id*. § 4332(2)(C).
[111] 16 U.S.C. § 1531 et seq.
[112] *Id*. § 1563(a)(1). A species is considered "endangered" if it "is in danger of extinction throughout all or a significant portion of its range." *See id*. § 1532(6). A species is "threatened" if it "is likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range." *See id*. § 1532(20).
[113] 43 C.F.R. §§ 1610.3-2 & 1610.5-5.
[114] *Id*. § 1610.5-5(a).
[115] *Id*. § 1610.5-5(e).

(B) Obtaining Approval to Use Federal Forest Land

Activities on federal forest land must generally be permitted or otherwise authorized by the Forest Service under the National Forest Management Act ("NFMA").[116] Pursuant to NFMA, the Forest Service issues "special use authorizations" for land uses other those involving the harvesting of timber or similar forest products, mineral development, grazing and livestock uses, and road use.[117] The Forest Service may waive the requirement for a special use authorization if it determines that an activity "will have such nominal effects on [federal forest] lands, resources, or programs that it is not necessary to establish terms and conditions in a special use authorization to protect [the] lands and resources or to avoid conflict with . . . programs or operations."[118] Waivers are granted on a case-by-case basis, taking into account the potential health, safety, and environmental impacts of the activity.[119] Where an enhanced weathering project is shown to have no or minimal adverse effects, the developer may qualify for a waiver. To provide added certainty to developers, the Forest Service could issue a guidance document or similar statement, outlining the circumstances in which waivers may be available for enhanced weathering projects.

Absent a waiver, enhanced weathering projects on federal forest land will require a special use authorization from the Forest Service.[120] Multiple authorizations may be required for some projects (e.g., those involving road construction).[121] Before issuing an authorization, the Forest Service must generally conduct an environmental review under NEPA and, as part of that process, engage in public consultation.[122] If the authorized use could adversely affect endangered or threatened species or their habitat, the Forest Service must also consult with FWS under the ESA.[123]

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[116] 16 U.S.C. § 1600 et seq.
[117] 36 C.F.R. § 251.50(a).
[118] *Id*. § 251.50(e)(1).
[119] *See generally*, FOREST SERVICE, DETERMINATION OF NOMINAL EFFECTS: FREQUENTLY ASKED QUESTIONS (2016), https://perma.cc/4U3T-KY89.
[120] 36 C.F.R. § 251.50(a).
[121] The Forest Service may issue permits, leases, or easements authorizing road construction. See *Id*. § 251.53.
[122] For a discussion of when NEPA applies to special use authorizations, *see* FOREST SERVICE, NATIONAL ENVIRONMENTAL POLICY ACT AND SPECIAL USES: FREQUENTLY ASKED QUESTIONS (2016), https://perma.cc/R6Q4-R7VQ. As part of its NEPA review of proposed roads, the Forest Service would need to consider whether road construction would lead to increased human activity in the area, and the environmental impacts of such activity. *See generally*, Swanson v. U.S. Forest Serv., 87 F.3d 339 (9th Cir., 1996) (holding that the Forest Service had met the requirements of NEPA by examining how road construction would affect "recreational activities in the area").
[123] 16 U.S.C. § 1563(a)(1).

As with public lands, all authorized uses of federal forest land must be consistent with any applicable land use plan, issued by the Forest Service pursuant to NFMA.[124] Unlike BLM, however, the Forest Service considers activities to be consistent with land use plans where they occur on land that the plan either (1) "identifies as suitable for that type of . . . activity" or (2) "is silent with respect to its suitability" for the activity.[125] It would, therefore, not be necessary to amend existing land use plans to specifically allow enhanced weathering.

(C) Fees for Using Public and Federal Forest Lands

Authorized users of public and federal forest land must generally pay rental fees reflecting "fair market value."[126] However, both BLM and the Forest Service have broad discretion to waive rental fees, including for projects that provide "a valuable benefit to the public at large."[127] Enhanced weathering projects may qualify for a rent waiver or reduction on the basis that they deliver public benefits in the form of climate change mitigation.

3.1.2 State Land

State governments own over 197.5 million acres of land in the U.S.[128] States with large land holdings include Alaska (105.8 million acres), New York (11.1 million acres), Arizona (9.1 million acres), New Mexico (8.7 million acres), Minnesota (5.4 million acres), and Montana (5.2 million acres).[129] Types of land under state ownership vary, but many states have large holdings of forest land, which could be used for enhanced weathering. Enhanced weathering could also be performed on coastal areas, such as beaches, along inland waterways, or in wetlands (together "aquatic lands"), which are often state-owned. This subpart discusses key issues associated with the use of state-owned lands for enhanced weathering.

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[124] 36 C.F.R. § 219.15(b).
[125] *Id*. § 219.15(d).
[126] *Id*. § 251.57(a) (providing that the holder of a special use authorization issued by the Forest Service must pay rental fees "based on the fair market value of the rights and privileges authorized"); 43 C.F.R. § 2920.8 (providing that the holder of a land use authorization issued by BLM must pay a rental fee that is "no . . . less than fair market value").
[127] 36 C.F.R. § 251.57(b) (providing that the Forest Service may waive "[a]ll or part of the fee . . . when equitable and in the public interest"); 43 C.F.R. § 2806.15 (providing that "BLM may waive or reduce your rent if you show BLM that . . . [y]ou provide without charge, or at reduced rates, a valuable benefit to the public at large").
[128] NATIONAL RESOURCES COUNCIL OF MAINE, PUBLIC LAND OWNERSHIP BY STATE (undated),https://perma.cc/ZW2T-FRAT.
[129] The remaining states have land holdings ranging in size from 24,000 acres to 4.7 million acres. *See id*.

(A) Enhanced Weathering Projects on State Forest Lands

Much state-owned forest land, particularly in the western U.S., was acquired through federal land grants under which states received land for the specific purpose of generating revenue to fund public education.[130] Many states have Constitutional or legislative provisions declaring that the land is held in trust for the benefit of educational institutions and requiring it to be managed accordingly.[131] Since the goal is to generate revenue from the land, states permit its use by third-parties, subject to the payment of fees.[132] While state permitting programs were generally designed to facilitate extractive uses of the land, such as mineral development and timber harvesting, many also allow for other activities. In Montana, for example, the state board of land commissioners has broad authority to issue land use licenses for activities "other than grazing, timber or agriculture" on school trust land.[133] To the extent similar provisions do not already exist elsewhere, states could enact legislation authorizing enhanced weathering on school trust land, with a permit from the relevant land management agency.

Each state has its own administrative regime for permitting the use of state-owned forest and other land, but most employ a process similar to that used by BLM and the Forest Service. Like their federal counterparts, state land management agencies often develop land use plans, which establish resource goals for different areas, specify management practices to achieve the goals, and identify uses consistent with the goals and practices.[134] State land use plans are typically developed with public input. Several states have environmental review laws similar to NEPA, under which state agencies must prepare EISs or similar documents before issuing or amending a land use plan.[135] An

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[130] Ross N. Brown et al., *State Timber Sale Programs, Policies, and Procedures: A National Assessment*, 110 J. FORESTRY 239, 239 & 247 (2012)

[131] *See e.g.*, MINN. CONSTITUTION, Art. XI, § 14; MINN. STAT. § 84.027, Subd. 18.

[132] *See generally*, Andy Laurenzi, Lincoln Institute of Land Policy, *State Trust Lands: Balancing Public Value and Fiduciary Responsibility*, LAND LINES (July 2004), https://perma.cc/MW2K-NLPB.

[133] MONT. ADMIN. R. 36.25.103(14) & 36.25.103.

[134] *See e.g.*, N.Y. Dep't of Envtl. Conservation, *Recreation and Unit Management Plans*, STEWARDSHIP OF DEC LANDS, https://perma.cc/2HSC-WYEB (last visited Sept. 17, 2020).

[135] In New York, for example, the State Environmental Review Quality Act requires preparation of an EIS for any action with potentially significant adverse environmental impacts. *See* N.Y. ENVTL. CONSERV. LAW § 8-0101 et seq. Fifteen other states and the District of Columbia have similar "little NEPA" statutes. *See* Patrick Marchman, "Little NEPAs": State Equivalents to the National Environmental Policy Act in Indiana, Minnesota and Wisconsin (Oct. 8, 2012) (unpublished capstone paper), https://perma.cc/4EA9-RD33.

additional environmental review may also be required before the state agency permits individual activities.

Some states have rules restricting activities in designated forest areas. In New York, for example, approximately 2.6 million acres of land in the Adirondack and Catskill State Parks have been designated as a "forest preserve."[136] Article XIV of the New York State Constitution declares that the forest preserve "shall be forever kept as wild forest lands" and "shall not be leased, sold or exchanged, or be taken by any corporation, . . . nor shall the timber thereon by sold, removed or destroyed."[137] The term "wild forest lands" is not defined in the New York State Constitution and has been the subject of little judicial discussion.[138] The New York Department of Environmental Conservation ("NYDEC") has interpreted it as requiring maintenance of the "natural conditions" of the forest preserve.[139] Consistent with this view, the New York Attorney-General has concluded that activities may be permitted within the forest preserve, where they do not impair the wild or natural character of the land.[140] Activities can, however, result in some changes to the natural environment. Thus, for example, construction within the preserve has been found to be permissible even where it would require the removal of a small number of trees and other vegetation, the relocation of rocks, and the grading and leveling of soil.[141] Activities must not result in the removal or destruction of significant trees, however.[142] Exactly where the threshold lies is uncertain.

The permissibility of enhanced weathering projects within the forest preserve will need to be assessed on a case-by-case basis, taking into account the activities performed as part of the project

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[136] N.Y. Dep't of Envtl. Conservation, *New York's Forest Preserve*, FORESTS, https://perma.cc/2R6N-N9KX (last visited Aug. 18, 2020).
[137] N.Y. CONSTITUTION, Art. XIV, § 1.
[138] The courts have generally focused on the second part of Article XIV, requiring that timber within the forest preserve not be harvested or destroyed, and not discussed the requirement that preserve be kept forever "wild." *See e.g.,* Ass'n for Prot. Of Adirondacks v. MacDonald, 253 N.Y. 234 (3rd Dept. 1930).
[139] N.Y. DEP'T OF ENVIRONMENTAL CONSERVATION, CATSKILL PARK STATE LAND MASTER PLAN 31 (2008), https://perma.cc/9864-MXR7.
[140] 1937 N.Y. Op. Atty. Gen. 242 (indicating that the movement of topsoil from one part of the forest preserve to another is permissible, provided that it "does not impair the preservation of the "wild forest" character" of the land).
[141] Protect the Adirondacks! Inc. v. N.Y. Dept. of Envtl. Conservation, 175 A.D.3d 24, 28-29 (3rd Dept. 2019) (upholding the construction of certain snowmobile trails through the forest preserve, despite the fact that it required "the removal of trees, brush, rocks, stumps, ledges and other natural features, the grading and leveling of the trails, and the cutting of side slopes").
[142] *Id*. at (finding that the construction of a second set of snowmobile trails, requiring the removal of approximately 25,000 trees, involved "an unconstitutional destruction of timber").

and their impact on the natural environment. Projects that merely involve applying reactive materials to land, with no subsequent tilling or similar soil disturbance, are likely permissible because they result in no or minimal changes to the land. However, roads or other access routes could not be constructed in connection with such projects, at least where construction would necessitate the removal of a large number of trees. There are also restrictions on the use of motorized vehicles, both on existing roads and in roadless areas, in some parts of the forest preserve.[143]

(B) Enhanced Weathering Projects on State Aquatic Lands

Ownership of aquatic lands varies within and between states. Coastal states own most tidelands, which lie below the high-water mark along the coast, and go from submerged to exposed as the tide moves.[144] Tidelands are thought to be particularly well suited to enhanced weathering because the movement of the tide agitates the reactive materials and thereby accelerates their weathering.[145] Coastal and inland wetlands, which again are often state-owned, may also be suitable sites for enhanced weathering.

The use of state-owned aquatic lands typically requires a permit or other authorization from the state agency responsible for managing those lands and is subject to the payment of fees.[146] Some states share management of aquatic lands with local governments. In Washington, for example, the Shoreline Management Act establishes a "cooperative program of shoreline management between local government and the state."[147] Pursuant to the Act, and based on guidelines issued by the state Department of Ecology, local governments develop and implement Shoreline Management Programs that govern the use of state waters and abutting land.[148] Any shoreline use involving "development," which is defined to include "filling" and "dumping," must be consistent with the applicable local government program.[149] A permit must be obtained from the local government for

[143] N.Y. COMP. CODES R & REGS tit 6, §§ 196.1-196.8.
[144] Tidelands can also be privately owned. *See generally*, WASHINGTON STATE DEPARTMENT OF NATURAL RESOURCES, BOUNDARIES OF STATE-OWNED AQUATIC LAND (Undated), https://perma.cc/MUW2-KZEZ.

[145] *See supra* Part 2.1.
[146] *See e.g.*, N.J. STAT. § 13:1B-13.10 (providing for the fixing of rental fees for the use of tidelands "based upon the fair market value of the land owned by the State").
[147] WASH. REV. CODE § 90.58.050.
[148] *Id*. §§ 80.58.060 & 80.58.080. *See also id*. § 80.58.030(2)(d) (defining "shorelands").
[149] *Id*. § 80.58.140(1). *See also id*. § 80.58.030(3)(a) (defining "development").

any "substantial development," of which the total cost or fair market value exceeds $5,000, or which would "materially interfere with normal public use" of water or land.[150]

Other states also require activities involving "filling" or "dumping" in aquatic lands to be permitted.[151] Several states require permits for all such activities, regardless of their cost, value, or impact.[152] In some states, however, permitting requirements only apply in designated areas.[153]

State statutes rarely define what constitutes "filling" or "dumping," but those terms are often interpreted as encompassing any discharge of materials, such as occurs during enhanced weathering. Some states expressly require permits for activities involving the discharge of rock or other materials onto aquatic lands. In Connecticut, for example, any person "dumping, filling, or depositing [into a wetland] any soil, stones, sand, gravel, mud, aggregate of any kind, rubbish or similar material" must hold a permit issued by the state Department of Energy and Environmental Protection.[154]

3.2 Environmental Permits Required for Enhanced Weathering Projects

As well as obtaining approval to use private, federal, or state land, enhanced weathering project developers may also need to secure various environmental permits. The specific permitting requirements will depend on the design of the enhanced weathering project, including where it is conducted, the materials used, and how they applied to land. Three potentially applicable

[150] *Id*. § 80.58.140(2). *See also id*. § 80.58.030(3)(e) (defining "substantial development").
[151] *See e.g.*, 7-7500-7502 DEL. ADMIN. CODE § 6.1.1 (providing that "no activity may take place in wetlands without a permit"). *See also id*. § 5.0 (defining "activity" to include, among other things, "filling").
[152] *Id*.
[153] *See e.g.,* N.C. GEN. STAT. § 113A-118(a) (requiring "every person, before undertaking any development in any area of environmental concern, [to] obtain . . . a permit"). *See also id*. §§ 113A-103(5) (defining a "development" as an activity involving "filling" or "dumping" (among other things) & 113A-113 (providing for the designation of "areas of environmental concern" in which developments must be permitted).
[154] CONN. GEN. STAT. § 22a-32 (providing that "[n]o regulated activity shall be conducted upon any wetland without a permit"). *See also id*. § 22a-29 (defining "regulated activity" to include, among other things, "dumping, filling or depositing" of materials). *See also* NEW YORK COMP. CODES R. & REGS., tit. 6, §§ 661.8 (providing that "[n]o person shall conduct a new regulated activity . . . on any tidal wetland or any adjacent area unless such person has first obtained a permit") & § 661.4(ee) (defining "regulated activity" to include "any form of dumping, filling or depositing . . . of any soil, stones, sand, gravel, mud, rubbish or fill of any kind").

permitting regimes are discussed in this Subpart. Other permitting regimes could also apply to some enhanced weathering projects.[155]

3.2.1 Air Pollution Permits

Enhanced weathering projects that involve applying ground rock to land may, depending on the size of the rock particles, be regulated as a source of particulate matter pollution under the Clean Air Act ("CAA").[156] Built on the principle of "cooperative federalism," the CAA divides regulatory authority between the federal Environmental Protection Agency ("EPA"), which sets minimum standards designed to protect air quality, and the states, which are responsible for implementing and enforcing those standards.

Section 108(a)(1) of the CAA directs EPA to identify air pollutants that are emitted by numerous mobile or stationary sources and cause or contribute to air pollution which may reasonably be anticipated to endanger public health or welfare ("criteria pollutants").[157] Under section 109 of the CAA, for each identified criteria pollutant, EPA must establish National Ambient Air Quality Standards ("NAAQS") that specify maximum pollutant concentrations below which air quality is considered acceptable from a public health and welfare standpoint.[158] Specifically EPA must establish "primary" NAAQS, "the attainment and maintenance of which . . . are requisite to protect the public health," and "secondary" NAAQS, which are "requisite to protect the public welfare from any known or anticipated adverse effects associated with the presence of [the] pollutant in the ambient air."[159] The primary and secondary NAAQS are implemented through enforceable plans, known as State Implementation Plans ("SIPs"), that are prepared by the states and approved by EPA. In some areas where SIPs have not been adopted, EPA prepares and may enforce Federal Implementation Plans ("FIPs").

EPA has established primary and secondary NAAQS for two classes of particulate matter:

(1) inhalable particles that are 2.5 microns or less in diameter ("PM2.5"); and

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[155] For example, enhanced weathering projects that adversely affect listed endangered or threatened plant or animal species may need to be permitted under the ESA. *See* 16 U.S.C. §§ 1538 (prohibiting the "take" of listed species) & 1539 (providing for the issuance of permits authorizing "take" that is "incidental to, and not the purpose of, the carrying out of an otherwise lawful activity").

[156] 42 U.S.C. § 7401 et seq.

[157] *Id*. § 7408(a)(1).

[158] *Id*. § 7409(a).

[159] *Id*. § 7409(b).

(2) inhalable particles that are 10 microns or less in diameter ("PM10").[160]

While NAAQS have not been established for larger particles, exceeding ten microns in diameter, they are regulated in some states through SIPs.[161]

It is uncertain what size rock particles will be used for enhanced weathering projects. Research indicates that the finer the particles used, the higher the rates of carbon sequestration achieved.[162] However, producing finer particles requires more energy for grinding, which increases costs and may offset some or all of the climate benefits of enhanced weathering (i.e., if the energy is generated at facilities emitting carbon dioxide).[163] Moreover, because ultrafine particles are more easily inhaled, their use would heighten public health risks.[164] Given this, some researchers have suggested using rock particles measuring twenty to fifty microns in diameter, though smaller particles could also be used.[165] Enhanced weathering projects that use rock particles measuring 10 microns or less would be regulated as a source of PM10.

Under the CAA, a permit from EPA or an authorized state or local authority is required to construct or modify of any "major stationary source" of PM10 or other air pollutants regulated under the Act.[166] The size threshold for "major" stationary sources varies depending on local air quality (among other things). In areas that have already attained the NAAQS ("attainment areas"), a source is generally considered "major" if it emits, or has the potential to emit, 250 tons or more of a pollutant annually.[167] In non-attainment areas, facilities emitting smaller amounts of pollutants may be classed as "major."[168]

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[160] National Ambient Air Quality Standards for Particulate Matter, 78 Fed. Reg. 3086 (Jan. 15, 2013).
[161] *See e.g.*, 9 VA. ADMIN. CODE § 5-80-1105(C).
[162] *See generally*, Strefler et al., *supra* note 28, at 034011)(finding that weathering rates "can be enhanced by several orders of magnitude through grain size reduction").
[163] *Id*. at 034014 (concluding that a "smaller target grain size increases the overall energy demand for the rock grinding . . . and thus cost").
[164] *Id*. at 034016 (noting that public health concerns would arise "if the target grain size is strongly decreased to compensate for low weathering rates").
[165] *Id*. at 034015 (describing 20 micrometers as "a typical and technically rather easy to achieve diameter").
[166] 42 U.S.C. §§ 7475, 7502, & 7503.
[167] Certain sources emitting 100 tons or more per year in attainment areas are considered "major" emissions sources under the CAA. *See* 42 U.S.C. § 7479(1).
[168] The "major source" threshold varies depending on the classification of the non-attainment area.

Certain activities related to enhanced weathering, such as rock grinding, may require a CAA permit if they result in PM10 emissions above the "major source" threshold.[169] However, CAA permits are unlikely to be required for the actual performance of enhanced weathering projects, wherein ground rock is applied to land. This is because the CAA permitting requirements only apply to "stationary" emission sources and land application is performed using vehicles or other mobile equipment.[170]

While the CAA only requires permits for major stationary emissions sources, some states have, through their SIPs, established permitting requirements for other sources. In California, for example, permits are generally required to construct or operate any "article, machine, equipment, or other contrivance" that releases particulate matter within the San Joaquin Valley Air Pollution Control District.[171] While there is an exemption for "motor vehicles," it does not extend to "emissions units mounted on such vehicles," which must be permitted.[172] Thus, for example, a permit would be required to operate a vehicle-mounted rock spreader or similar equipment used to apply materials to land for enhanced weathering (i.e., unless another exemption applied). In some cases, the equipment used in enhanced weathering projects may qualify as a "low emitting unit"—i.e., defined as a unit that emits no more than two pounds of particulate matter per day or seventy-five pounds per year—that is exempt from permitting.[173] There is also an exemption for certain equipment used in agricultural activities, including crop production, that could apply to enhanced weathering projects performed on agricultural land.[174]

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[169] Rock grinding and other activities involved in sourcing materials for use in enhanced weathering will be discussed in a forthcoming paper by the author.

[170] 42 U.S.C. §§ 7475(a) (requiring each "major emitting facility" in an attainment area to be permitted) & 7479(1) (defining a "major emitting facility" as a "stationary source[] of air pollutants" which emit, or have the potential to emit, above the major source threshold). *See also* id. §§ 7502(c)(5) (requiring permits for "major stationary sources" in non-attainment areas) & 7602(j) (defining "major stationary source" to mean "any stationary facility or source of air pollutants" which emits, or has the potential to emit, above the major source threshold).

[171] San Joaquin Valley Air Pollution Control Dist., Cal., Rule 2010. The San Joaquin Valley Air Pollution Control District comprises all or part of eight counties in the central valley of California, namely: (1) San Joaquin County, (2) Stanislaus County, (3) Merced County, (4) Madera County, (5) Fresno County, (6) Kings County, (7) Tulare County, and (8) part of Kern County. See generally, San Joaquin Valley Air Pollution Control Dist., *District Information*, ABOUT THE DISTRICT, https://perma.cc/9WX3-6RVP (last visited Sep. 17, 2020).

[172] San Joaquin Valley Air Pollution Control Dist., Cal., Rule 2010.

[173] *Id*. §§ 3.4 & 6.16.

[174] *Id*. §§ 3.1 & 6.20.

As well as requiring enhanced weathering projects to be permitted, SIPs may also impose other requirements thereon. SIPs often include provisions aimed at limiting dust from the handling, transport, storage, and use of rock, gravel, sand, and similar "bulk" materials. In Arizona, for example, persons storing bulk materials in the open must cover the storage piles with a tarp or similar material or apply water to them to minimize dust.[175] Similarly, in Virginia, water or chemicals must be applied to storage piles and other surfaces that could create dust or other "reasonable precautions" taken to prevent dust becoming airborne.[176] Enhanced weathering projects in which silicate materials are stored in piles, prior to their application to land, would need to comply with these and similar requirements in other states.

3.2.2 Water Pollution Permits

Depending on where and how they are performed, enhanced weathering projects may also require a permit under the Federal Water Pollution Control Act (commonly known as the Clean Water Act ("CWA")).[177] First enacted in 1949, and substantially revised in 1972, the CWA aims to "restore and maintain the chemical, physical, and biological integrity of the Nation's waters."[178] To that end, the CWA prohibits "the discharge of any pollutant by any person," unless he/she/it holds a permit issued under the National Pollutant Discharge Elimination System ("NPDES").[179]

The CWA defines "pollutant" broadly to include "rock, sand, cellar dirt and industrial, municipal, and agricultural waste discharged into water."[180] Under this definition, the ground silicate rock proposed for use in enhanced weathering would constitute a pollutant. Artificial silicates would also be pollutants if they take the form of "industrial waste." That term is not defined in the CWA but, in ordinary parlance, is used to refer to worthless or superfluous by-products from industrial processes.[181] Many artificial silicates, such as mine tailings and cement kiln dust, are

[175] Maricopa County, Az., Air Pollution Control Regulations § 305.5.
[176] 9 VA. ADMIN. CODE § 5-40-90.
[177] 33 U.S.C. § 1251 et seq.
[178] *Id*. § 1251(a).
[179] *Id*. § 1311(a) (providing that, subject to certain exceptions, "the discharge of any pollutant by any person shall be unlawful"). *See also id*. § 1342(a)(1) (authorizing the EPA Administrator to "issue a permit for the discharge of any pollutant, or combination of pollutants, notwithstanding section 1311(a) of this title").
[180] *Id*. § 1362(6). See a
[181] Merriam-Webster Dictionary, *Waste*, http://www.merriam-webster.com/dictionary/waste (last visited June 19, 2020).

secondary products derived from industrial activities (e.g., mining and cement production) and thus may be considered industrial wastes.

For the purposes of the CWA, a pollutant is "discharged" where it is added to waters of the U.S. from a "point source,"[182] defined as "any discernible, confined and discrete conveyance."[183] The definition of "point source" has been held to include aircraft, trucks, and other vehicles from which materials are dispersed. For example, in *League of Wilderness Defenders v. Forsgren* ("*Forsgren*"), the U.S. Court of Appeals for the Ninth Circuit held that "an airplane fitted with tanks and mechanical spraying apparatus" for disbursing insecticides is a "discrete conveyance" and thus qualifies as a point source under the CWA.[184] The court further held that, because the airplane was spraying insecticides over forested areas that contained rivers and other water bodies, it was discharging pollutants into waters of the U.S. and thus required a NPDES permit.[185] Applying the reasoning in *Forsgren*, a NPDES permit would be needed for any enhanced weathering project that involved dropping silicate materials from an aircraft over water bodies.

Enhanced weathering projects in which materials are applied directly to land using trucks or other spreading equipment may also require NPDES permits in some cases, including where storm water runoff from the application site is channeled or directed into water bodies. Regulations adopted by EPA under the CWA define the "addition of pollutants into waters of the [U.S.] from surface runoff which is collected and channeled by man" ("directed runoff") as a point source discharge.[186] Notably, however, the definition excludes directed runoff that is comprised entirely of "return flows from irrigated agriculture" or "agricultural storm water" ("agricultural runoff").[187] The definition also excludes runoff that flows naturally over land into water bodies without any

[182] *Id*. §§ 1362(16) (defining "discharge" to mean "a discharge of a pollutant") & 1362(12) (defining "discharge of a pollutant" to mean "(A) any addition of any pollutant to navigable waters from any point source, (B) any addition of any pollutant to the waters of the contiguous zone or the ocean from any point source other than a vessel or other floating craft"). *See also id*. §1362(7) (defining "navigable waters" to mean "waters of the United States, including the territorial sea").

[183] *Id*. § 1362(6).

[184] League of Wilderness Defenders / Blue Mts. Biodiversity Project v. Forsgren, 309 F.3d 1181, 1185 (2002).

[185] *Id*.

[186] 40 C.F.R. § 122.2.

[187] *Id*. (providing that the "term [point source] does not include return flows from irrigated agriculture or agricultural storm water runoff"). *See also* 33 U.S.C. § 1362(14) (providing that "[t]he term point source . . . does not include agricultural stormwater discharges and return flows from irrigated agriculture").

intervention by man ("natural runoff").[188] Agricultural and natural runoff are treated as non-point source discharges and not subject to the permitting requirements in the CWA.[189]

While non-agricultural directed runoff is classified as a point-source discharge for the purposes of the CWA, a NPDES permit is only required therefor in specified circumstances, including where the runoff:

(1) is associated with a specified category of industrial activity;[190]

(2) is found to contribute to a violation of water quality standards;[191]

(3) is found to be a significant contributor of pollutants to waters of the U.S.;[192] or

(4) flows into a listed impaired water body and controls are found to be needed to ensure pollutant allocations for that water body are not exceeded.[193]

With respect to (1) above, EPA regulations identify eleven types of facilities "considered to be engaging in industrial activity."[194] Of particular relevance to enhanced weathering, the list includes "land application sites . . . that receive or have received any industrial waste, including those that are subject to regulation under subtitle D" of the Resource Conservation and Recovery Act ("RCRA").[195] As discussed further in Part 3.2.3 below, enhanced weathering projects that involve spreading artificial silicates on land are likely to be subject to regulation under subtitle D of RCRA, and thus will ordinarily require NPDES permits for any directed runoff. Enhanced weathering projects that use other materials not regulated as hazardous wastes under RCRA, such as ground silicate rock, would also require NPDES permits if they meet criterion (2), (3), or (4) above. Such projects may, however, fall under the agricultural runoff exemption when performed on irrigated cropland.

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[188] It should be noted that natural features in the land, which are used to catch and direct run-off, can be point source discharges for the purposes of the CWA.

[189] *See generally*, Northwest Envtl. Def. Ctr. v. Brown, 640 F.3d 1063, 1071 (2011) (indicating that "runoff is not inherently a nonpoint or point source of pollution. Rather, it is a nonpoint or point source . . . depending on whether it is allowed to run off naturally (and is thus a nonpoint source) or is collected, channeled, and discharged through a system of ditches, culverts, channels, and similar conveyances (and is thus a point source discharge)").

[190] 40 C.F.R. § 122.26(a)(1)(ii).

[191] 40 C.F.R. §§ 122.26(a)(1)(v) & (a)(9)(i)(D).

[192] *Id*.

[193] *Id*. § 122.26(a)(9)(i)(C).

[194] *Id*. § 122.26(b)(14).

[195] *Id*. § 122.26(b)(14)(v).

As noted above, NPDES permits are not required for directed run-off comprised entirely of "return flows from irrigated agriculture or agricultural storm water."[196] Neither the CWA, nor EPA's current implementing regulations, define what constitutes agricultural "return flows" and "storm water." In the past, however, EPA has defined agricultural "return flows" to mean "surface water . . . containing pollutants which result from the controlled application of water by any person to land used primarily for crops, forage growth, or nursery operations."[197] At least one federal court has held that, for runoff to be considered an agricultural return flow, the amount of water applied to the land must not greatly exceed the absorptive capacity of the soil.[198] Few other requirements have been imposed, however, with the courts generally taking a broad view of the agricultural runoff exemption.[199] The exemption may be available where enhanced weathering is performed on irrigated cropland and the only discharge into waterways takes the form of runoff from the controlled irrigation of that land.

Where required, NPDES permits for enhanced weathering projects may be issued by EPA, or an authorized state body.[200] EPA has issued a "general permit" for discharges comprising run-off

[196] 33 U.S.C. § 1342(l)(1); 40 C.F.R. § 122.3(f). *See also* 40 C.F.R. § 122.2 (providing that "return flows from irrigated agriculture" and "agricultural stormwater runoff" do not constitute point source discharges requiring a NDPES permit).

[197] This definition was included in regulations adopted by EPA in 1976. The regulations required permits to be obtained for any "agricultural point source" which was defined to mean "any discernible, confined and discrete conveyance from which any irrigation return flow is discharged into navigable waters." *See* National Pollutant Discharge Elimination System, Application of Permit Program to Agricultural Activities, 41 Fed. Reg. 28,493, 28,496 (July 12, 1976). Congress subsequently amended the CWA to exclude irrigation return flows from permitting requirements. While no definition of irrigation return flows was included in the amended CWA, the Senate Report on the amendments defined irrigation return flows as "conveyances carrying surface irrigation return as a result of the controlled application of water by any person to land used primarily for crops." *See* Federal Water Pollution Control Act, Pub. L. No. 95-217, 91 Stat. 1566, 1577 (1977); S. Rep. No. 95-370, 35 (1977).

[198] United States v. Oxford Royal Mushroom, 487 F. Supp. 852 (E.D. Pa. 1980). *Cf.* Heibenthal v. Meduri Farms, 242 F. Supp. 2d 885, 888 (D. Or. 2002) (suggesting that the exemption for agricultural return flows may apply even where water is applied to fields "in excess of the crops' actual absorption" capacity).

[199] *See e.g.*, Heibenthal, 242 F. Supp. 2d at 888 (holding that all discharges associated with agricultural operations are exempt from the NPDES permit requirements, unless they are from concentrated animal feeding operations). *See generally*, Andrew C. Hanson & David C. Bender, *Irrigation Return Flow or Discrete Discharge? Why Water Pollution from Cranberry Bogs Should Fall Within the Clean Water Act's NPDES Program*, 37 ENVTL. L. 339, 349 (2007).

[200] Under section 402(b) of the CWA, states can apply to EPA for authorization to administer their own discharge permitting programs, often referred to as State Pollutant Discharge Elimination System ("SPDES") programs. *See* 33 U.S.C. § 1324(b). As of August 2020, forty-seven states authorized SPDES programs. *See*

from specified industrial facilities, including land application sites regulated under RCRA, in the areas where it retains responsibility for permitting.[201] Dischargers covered by the general permit can submit a "notice of intent" to operate under it, rather than applying to EPA for an individual NPDES permit via the process described below. Obtaining coverage under a general permit is, therefore, far simpler and quickly than securing an individual NPDES permit. As such, EPA should consider issuing general permits for discharges associated with other enhanced weathering projects, which do not involve RCRA land application sites.

Applications for individual NPDES permits must be submitted to the relevant EPA regional office or state agency, generally at least 180 days before any discharge occurs,[202] and include information about the nature and location of the discharge.[203] Before issuing a permit, the EPA office or state agency must notify the public and invite comments.[204] Where EPA is the permitting agency, the state in which the permitted discharge will occur must issue a certificate verifying that the discharge will comply with all applicable water quality requirements or waive certification, before a permit can be issued.[205] Additionally, if the permitted discharge will originate from a new source constructed at a site where no existing source is located, or will replace or operate independently of an existing source, EPA must conduct an environmental review under NEPA before issuing a

Envtl. Prot. Agency, *NPDES State Program Authority*, NATIONAL POLLUTANT DISCHARGE ELIMINATION SYSTEM (NPDES), https://perma.cc/YQJ9-NQSE (last updated Aug. 31, 2020).

[201] *See* ENVTL. PROT. AGENCY, MULTI-SECTOR GENERAL PERMIT FOR STORMWATER DISCHARGES ASSOCIATED WITH INDUSTRIAL ACTIVITY (2015), https://perma.cc/TPC9-VRW8. The 2015 general permit for industrial stormwater discharges expired on June 3, 2020, but was administratively continued. *See* Envtl. Prot. Agency, *Stormwater Discharges from Industrial Activities: EPA's 2015 Multi-Sector General Permit (MSGP)*, NATIONAL POLLUTANT DISCHARGE ELIMINATION SYSTEM, https://perma.cc/EUH7-NX6M (last updated Aug. 24, 2020). At the time of writing, EPA was in the process of developing a new general permit for industrial stormwater discharges. *See* Envtl. Prot. Agency, *Stormwater Discharges from Industrial Activities: Proposed 2020 MSGP*, NATIONAL POLLUTANT DISCHARGE ELIMINATION SYSTEM, https://perma.cc/Z9JA-YVER (last updated Aug. 24, 2020).

[202] 40 C.F.R. §§ 122.21(a)-(c) & 124.3. Where EPA determines that a discharge comprising directed runoff requires a permit because of its contribution to water pollution, the discharger must apply for a permit within 60 days of being notified of the EPA's determination. *See* 40 C.F.R. § 124.52.

[203] *Id*. § 122.21(f)-(r).

[204] *Id*. §§ 124.10 - 124.12.

[205] 33 U.S.C. § 1341(a)(1); 40 C.F.R. § 124.53(a).

permit.[206] Some state agencies are also required to conduct environmental reviews before issuing permits.[207]

Individual NPDES permits may be issued for up to five years[208] and impose various conditions on dischargers.[209] Among other things, permits include effluent limitations, specifying the maximum amount of chemical, physical, and other pollutants that may be discharged.[210] EPA has established effluent limitations guidelines for discharges associated with several classes of industrial activity.[211] Enhanced weathering projects do not fall within any of the listed classes; effluent limitations for discharges associated with such projects will, therefore, need to be established on a permit-by-permit basis.

3.2.3 Waste Management Permits

Where enhanced weathering is performed using artificial silicates, RCRA may also apply. RCRA establishes a national framework for the regulation of solid waste handling, storage, and disposal. Under section 2(27) of RCRA, "solid waste" is defined as any "discarded material, including solid, liquid, semisolid or contained gaseous material resulting from industrial, commercial, mining and agricultural operations."[212] This definition is elaborated on in EPA regulations issued pursuant to RCRA. The regulations define "discarded materials" as those that are "abandoned, recycled, [or] considered inherently waste-like."[213] The regulations further provide that materials are "abandoned" where they are "disposed of"[214] and define "disposal" broadly to include any "discharge, deposit, . . . or placing of any solid waste . . . into or on any land or water such that [it] or any constituent . . . may enter the environment or be emitted into the air or discharged into any waters."[215]

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[206] 33 U.S.C. § 1371(c); 40 C.F.R. §§ 122.29 & 124.61.
[207] *See supra* note 135.
[208] 40 C.F.R. § 122.46.
[209] *See generally* 40 C.F.R. §§ 122.41 - 122.45.
[210] *See generally* 33 U.S.C. §§ 1311-1312, 1314 & 1316; 40 C.F.R. § 122.44. Effluent limitations are generally, but not always, technology-based (i.e., the limits are set based on the pollution controls that can be achieved using currently available technology).
[211] *See generally*, 40 C.F.R. Ch. 1, Subch. N.
[212] 42 U.S.C. § 6903(27).
[213] 40 C.F.R. § 261.2(a)(2)(i).
[214] *Id*. § 261.2(b).
[215] *Id.* § 257.2. *See also* 42 U.S.C. § 6903(3).

Artificial silicates used in enhanced weathering are likely to be considered "solid waste" for the purposes of RCRA. As discussed in Part 3.2.2 above, mine tailings, cement kiln dust, and other artificial silicates are waste by-products generated during industrial operations (e.g., mining and cement production). Under EPA's RCRA regulations, such materials are considered to be "discarded" when they are abandoned, including through disposal on land. The discharge of artificial silicates as part of an enhanced weathering project could qualify as "disposal" under the regulations because it involves "placing" materials on land and results in them "enter[ing] the environment" (even though the materials are placed on land for the purposes of enhanced weathering and not discarded or disposed of in the ordinary sense of the word). Where artificial silicates are stored on land prior to their use in enhanced weathering, in a manner that could result in them entering the environment (e.g., because they are not placed on a pad or liner), the act of storage could also constitute "disposal" for the purposes of RCRA.[216]

As discussed further below, if artificial silicates used in enhanced weathering are classified as "solid waste" under RCRA, projects that use them would be subject to various controls, which could limit project development. If Congress wanted to facilitate enhanced weathering using artificial silicates, it could amend RCRA to expressly provide that such materials, when stored on or applied to land in connection with an enhanced weathering project, do not constitute "solid waste" for the purposes of the Act.

RCRA establishes separate regulatory frameworks for hazardous waste (dealt with in subtitle C of the Act) and non-hazardous waste (dealt with in subtitle D). Hazardous waste is defined in section 2(5) of RCRA as:

> solid waste, or a combination of solid wastes, which because of its quantity, concentration, or physical, chemical, or infectious characteristics may:
> (A) cause, or significantly contribute to an increase in mortality or an increase in serious irreversible, or incapacitating reversible, illness; or

[216] *See generally*, Owen Elec. Steel Co. v. Browner, 37 F.3d 146, 150 (4th Cir. 1994) (holding that steel slag that was destined for use as construction aggregate was "solid waste" for the purposed of RCRA because it was not "immediately recycled for use in the same industry" as produced it and was stored on land prior to use). Where enhanced weathering is performed using natural silicates, such as ground rock, which are produced specifically for such use and not a by-product of another industrial process, RCRA would not apply their storage on land prior to use.

> (B) pose a substantial present or potential hazard to human health or the environment when improperly treated, stored, transported, or disposed of, or otherwise managed.[217]

Certain materials with these characteristics are, however, exempt from regulation as hazardous wastes. In October 1980, Congress enacted the Bentsen and Bevill Amendments to RCRA, which provided a conditional exemption for certain wastes, pending completion of a review by EPA.[218] Notably, the Bevill Amendment covered the key artificial silicates proposed for use in enhanced weathering—i.e., fly ash generated at fossil fuel power plants, cement kiln dust waste generated during cement production, and mining waste generated during the extraction, benefaction, and processing of ores and minerals (including mine tailings and slags).[219] After reviewing the characteristics of each waste, practices for waste handling and disposal, and the potential benefits and costs of additional regulation, EPA determined that fly ash, cement kiln dust, and most mining waste should be treated as non-hazardous.[220] Relevantly, within the mining waste category, EPA designated mine tailings from hard-rock mining operations and iron and steel slag as non-hazardous wastes.[221]

While the above wastes are exempt from regulation under subtitle C of RCRA (i.e., the provisions dealing with hazardous waste), they remain subject to subtitle D (i.e., dealing with non-hazardous waste). Under subtitle D, regulatory authority over non-hazardous waste is shared among the federal, state, and local governments.[222] At the federal level, EPA establishes minimum national standards for the management of non-hazardous wastes.[223] Those standards are implemented through state and local programs, which may incorporate additional or more stringent requirements (i.e., beyond those established by EPA).[224]

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[217] 42 U.S.C. § 6903(5).
[218] Solid Waste Disposal Act Amendments of 1980, Pub. L. 96-482,94 Stat. 2334 (1980) (codified at 42 U.S.C. § 6921(b)(2)-(3)).
[219] 42 U.S.C. § 6921(b)(3)(A)(i)-(iii).
[220] *See generally,* ENVTL. PROT. AGENCY, REPORT TO CONGRESS: WASTES FROM THE EXTRACTION AND BENEFACTION OF METALLIC ORES, PHOSPHATE ROCK, ASBESTOS, OVERBURDEN FROM URANIUM MINING, AND OIL SHALE (1985), https://perma.cc/869U-X5MW; ENVTL. PROT. AGENCY, REPORT TO CONGRESS: WASTES FROM THE COMBUSTION OF COAL BY ELECTRIC UTILITY POWER PLANTS (1988), https://perma.cc/64RK-RTLN; ENVTL. PROT. AGENCY, REPORT TO CONGRESS ON CEMENT KILN DUST (1993), https://perma.cc/66P8-T29A.
[221] 40 C.F.R. § 261.4(b)(7).
[222] 42 U.S.C. § 6931.
[223] *Id*. § 6942 – 6946.
[224] *Id*. § 6946 & 6947.

EPA has established national standards for the management of fly-ash and other so-called "coal combustion residuals" ("CCRs").[225] The standards include requirements with respect to the location, design, and operation of "CCR landfills," defined as "area[s] of land . . . that receive CCR."[226] For the purposes of this definition, land is considered to "receive" CCR where the material is deposited, dumped, or otherwise placed on the land.[227] As such, if fly ash were placed on land in an enhanced weathering project, that land may qualify as a CCR landfill and thus be subject to the EPA standards. This could have significant implications for the conduct of enhanced weathering projects using fly ash. Under the standards, projects could not take place in wetlands and certain other areas, which EPA has determined are unsuitable for CCR landfills.[228] Enhanced weathering projects would also have to comply with the design and operational requirements established in the standards. These include requirements to limit water entering, and capture run-off from, the site[229] which could hinder carbon sequestration because the weathering process requires water flow.[230]

EPA has not adopted standards dealing specifically with cement kiln dust or mining waste, but those materials are covered by general rules applicable to all non-hazardous solid wastes.[231] The rules are fairly limited but, relevantly, do impose some restrictions on the application of waste materials to cropland.[232] In general, and with some exceptions, waste materials must not be applied within three feet of land used to grow food-chain crops intended for human consumption or for feed for animals whose products are consumed by humans.[233]

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[225] 40 C.F.R. Pt. 257, Subpt. D. *See also id*. § 257.53 (defining "coal combustion residuals"). In 2019 and 2020, EPA proposed various revisions to the CCR rules, but those proposals were yet to be finalized at the time of writing. *See* Hazardous and Solid Waste Management System: Disposal of Coal Combustion Residuals from Electirc Utilities; Enhancing Public Access to Information; Reconsideration of Beneficial Use Criteria and Piles, 84 Fed. Reg. 40353 (Aug. 14, 2019); Hazardous and Solid Waste Management System: Disposal of CCR; A Holistic Approach to Closure Part B: Alternative Demonstration for Unlined Surface Impoundments; Implementation of Closure, 85 Fed. Reg. 12456 (Mar. 3, 2020).

[226] The definition of "CCR landfill" excludes surface impoundments, underground injection wells, salt dome formations, salt bed formations, underground or surface coal mines, and caves. *See* 40 C.F.R. § 257.53.

[227] *See generally*, Util. Solid Waste Activities Grp. V. Envtl. Prot. Agency, 901 F.3d 414, 440 (D.C. Cir. 2018).

[228] 40 C.F.R. § 257.61 (providing that "[n]ew CCR landfills . . . must not be located in wetlands" unless certain requirements are met).

[229] *Id*. §§.257.70 & 257.81.

[230] *See supra* Part 2.1.

[231] 40 C.F.R. Pt. 257, Subpt. A.

[232] 40 C.F.R. § 257.3-5.

[233] *Id*. *See also* § 260.10 (defining "food-chain crops").

States have imposed additional restrictions on the handling and disposal of solid wastes. In New York, for example, solid waste must be sent to approved facilities and cannot be applied to land or otherwise dealt with outside such facilities.[234] New York and several other states do, however, provide an exemption for solid waste that is put to "beneficial use."[235] While state rules vary, all require beneficial uses to be pre-approved through a beneficial use determination ("BUD") or similar instrument, which is typically issued by the state environmental agency.[236] Some state agencies have issued standing BUDs, which allow persons to use specified waste materials in specified ways, without obtaining individual approval from the agency.[237] While standing BUDs covering artificial silicates, such as fly ash and slag, have been issued in some states, none currently allow the use of those materials for enhanced weathering.[238] State agencies could support enhanced weathering using artificial silicates by issuing a standing BUD therefor. Unless and until that happens, project developers will need to obtain an individual or project-specific BUD for such use, which may be difficult in some cases.

Again, while there is some variation between state rules, most provide for the issuance of individual BUDs where solid waste is used as a substitute for other materials in a manner that is not environmentally harmful. As an example, the NYDEC can issue BUDs for activities involving the use of solid waste "as an effective substitute for a commercial product or raw material," provided the following conditions are met:

(1) the activity involves use, as opposed to disposal, of the waste;

(2) the waste will be managed as a commodity and is substituting for an analogous commercial product or raw material;

(3) at the point of use, the waste will not require decontamination or other processing;

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[234] N.Y. COMP. CODE R. & REGS. tit. 6, § 360.9(b). *See also id*. § 360.2(a) (defining "solid waste").

[235] *Id*. § 360.12. Beneficial use programs also exist in several other states. *See e.g.,* MINN. R. 7035.2860; N.J. ADMIN. CODE §§ 7:26-1.1 – 7:26-1.6.

[236] N.Y. COMP. CODE R. & REGS. tit. 6, § 360.12.

[237] For example, at the time of writing, the Minnesota Pollution Control Agency had issued seventeen standing BUDs and the NYDEC had issued twenty-eight. *See* MINN. R. 7035.2860, subp. 4; N.Y. COMP. CODE R. & REGS. tit. 6, § 360.12(c).

[238] *See e.g.*, MINN. R. 7035.2860, subp. 4(N) (establishing a standing BUD for "coal combustion fly ash . . . when used as an ingredient for production of aggregate that will be used in concrete and concrete products").

(4) a market exists or is reasonably certain to develop for the waste or a product into which it is incorporated;

(5) heavy metals and other pollutants (if any) are present in the waste at acceptable concentrations as determined by the NYDEC; and

(6) the proposed use will not significantly adversely affect public health or the environment.[239]

The application of these conditions to enhanced weathering projects raises several questions. While enhanced weathering projects are likely to meet conditions (1) and (2), the others, particularly (4), may be more difficult to satisfy.

With respect to condition (1), the terms "use" and "disposal" are not defined in NYDEC regulations. In general parlance, disposal refers to the act of discarding materials that are no longer useful, which is not the purpose of enhanced weathering. Rather, in enhanced weathering, silicate materials are used to capture and store carbon. Where enhanced weathering is performed using artificial silicates, those materials would be substituting for analogous commercial products (i.e., ground rock), satisfying condition (2). Compliance with conditions (3), (5), and (6) would need to be assessed on a case-by-case basis, taking into account the characteristics of the specific artificial silicates to be used. With respect to condition (4), it is not presently "reasonably certain" that a market will develop for artificial silicates, since that will depend largely on whether enhanced weathering projects can be commercialized, for example as a means of generating carbon credits.[240] If New York wanted to promote enhanced weathering using artificial silicates before its commercial potential was proven, the NYDEC could amend its regulations to waive requirement (4) for such projects. Other states could do the same.

3.3 Potential Liability for Damage Caused by Enhanced Weathering Projects

As discussed in Part 2.2 above, in some circumstances, enhanced weathering projects could pose risks to the environment. Where environmental damage occurs and individuals or the public

[239] N.Y. COMP. CODE R. & REGS. tit. 6, § 360.12(d)(3).

[240] There are currently no established protocols for verifying the permanence of carbon sequestration through enhanced weathering, which is a necessary pre-condition for projects to generate carbon credits. *See supra* Part 1.

at large are harmed as a result, the project developer could be liable under tort law principles of trespass or nuisance.[241]

Trespass is generally said to occur where a person "intentionally enters or causes tangible entry upon the land . . . of another."[242] While this general principle has been interpreted and applied differently in different states, courts typically agree that placing something on another's land may constitute trespass.[243] Courts have, in the past, found defendants liable for trespass when they have allowed polluting substances to flow onto neighboring land. In theory, then, an action for trespass could be brought by the owner of land onto which flows ground rock or other materials disbursed during an enhanced weathering project. In some states, however, landowners may find it difficult to prove trespass. Some state courts have held that trespass requires proof that a "physical, tangible object" intruded onto the land and that rock dust is "intangible and thus not actionable in trespass." For example, in *Adams v. Cleveland-Cliffs Iron Co.*, the Michigan Court of Appeals dismissed a trespass claim brought by landowners who alleged that rock dust from a nearby iron ore mine accumulated on their property.[244] The court reasoned that:

> [D]ust particles are tangible objects in a strict sense that they can be touched and are comprised of physical elements. However, . . . for practical purposes, dust, along with other forms of airborne particulate, does not normally present itself as a significant physical intrusion . . .
>
> Dust particles do not normally occupy the land on which they settle in any meaningful sense; instead they simply become part of the ambient circumstances of that space.[245]

Courts in some other states have upheld trespass claims based on intrusions by dust or other airborne particles. In *Roberts v. Permanente Corp*, for example, a California appeals court upheld a landowner's claim for damages for trespass after dust from a nearby cement plant and quarry settled on their land and "not only physically damaged it but also deprived them of their use and enjoyment

[241] While trespass and nuisance are distinct principles, state courts often conflate the two, particularly in cases involving claims resulting from environmental contamination. *See generally*, DAN B. DOBBS ET AL., THE LAW OF TORTS, 141 (2d ed. 2011).
[242] *Id*. at 125.
[243] Restatement (Second) of Torts, § 158.
[244] Adams v. Cleveland-Cliffs Iron Company, 602 N.W.2d 215 (Mich. Ct. App. 1999)
[245] *Id*. at 223.

thereof."[246] Notably, in California and certain other states, it is not necessary to prove that the defendant intended to cause harm or acted negligently in releasing the materials that caused the trespass. Rather, as the court observed in *Roberts v. Permanente Corp*, "[t]he doing of an act which will to a substantial certainty result in the entry of foreign matter upon another's land suffices for an intentional trespass to land upon which liability may be based."[247] In many situations, material applied to land for the purposes of enhanced weathering will be "substantially certain" to move onto neighboring properties where it may cause damage, thus potentially exposing the project developer to liability for trespass.

Enhanced weathering projects that result in materials flowing onto neighboring land or cause other pollution may also give rise to private or public nuisance claims.[248] State courts have traditionally defined private nuisance broadly to include "anything that annoys or disturbs the free use of one's property, or which renders its ordinary use or physical occupation uncomfortable."[249] Thus, for example, an enhanced weathering project that results in dust blowing onto neighboring land or contaminates soil or water thereon could give rise to a private nuisance claim. Again, however, claimants may encounter difficulties in some cases. Many (but not all) states require claimants to prove that the interference with their property was "intentional and unreasonable," "negligent or reckless," or the result of an "abnormally dangerous" activity.[250] In determining whether an activity is abnormally dangerous, the courts consider a range of factors, including the risks posed by the activity and whether those risks can be eliminated through the exercise of reasonable care, how common the activity is and its appropriateness to the location in which it occurred, and the extent to which the activity benefits the community.[251] In the context of enhanced weathering, project developers could argue that their activities deliver significant public benefits—

[246] Roberts v. Permanente, 188 Cal. App. 2d 529 (Cal. Ct. App. 1961).
[247] *Id*. at 530.
[248] It has been suggested that CDR project developers could be also be liable for nuisance if they withdrew enough carbon dioxide from the atmosphere "at a fast enough rate to arguably affect local environmental conditions or ecosystems," but this is unlikely in the case of enhanced weathering. *See generally*, Tracy Hester, *Negative Emissions Technologies and Direct Air Capture, in* LEGAL PATHWAYS TO DEEP DECARBONIZATION IN THE U.S. (Michael B. Gerrard and John C. Dernbach eds., 2019).
[249] Jill M. Fraley, Liability for Unintentional Nuisances: How the Restatement of Torts Almost Killed the Right to Exclude in Property Law, 121 W. Va. L. Rev. 419, 424 (2018).
[250] Restatement (Second) of Torts, § 822. *See also* Fraley, *supra* note 249, at 428-431 (discussing state courts' implementation of the test set out in the Restatement (Second) of Torts).
[251] Restatement (Second) of Torts, § 520.

i.e., by sequestering carbon and thus mitigating climate change—which outweigh any risks. Similar arguments could also be relied upon by developers in a public nuisance suit alleging that enhanced weathering or pollution therefrom interfere with a right held by the general public.

4. ENHANCED WEATHERING AT SEA

As with enhanced weathering on land, the regulation of sea-based enhanced weathering is highly uncertain. There are currently no international or domestic laws dealing specifically with sea-based enhanced weathering, but the practice could be subject to various general environmental and other laws. The application of those laws will depend on the specific design of each enhanced weathering project and where it occurs.

4.1 Jurisdiction Over the Seas

Regulatory jurisdiction over the seas is governed by international law. The relevant legal principles and their application in the U.S. are discussed in this part.

4.1.1 International Legal Framework Governing Offshore Jurisdiction

Under the 1982 United Nations Convention on the Law of the Sea ("UNCLOS"), each country has jurisdiction over areas within 200 nautical miles ("n.m.") of the low water line along its coast (known as the "baseline"), and further in some circumstances.[252] UNCLOS divides the 200 n.m. zone into three key parts, each of which has a different legal status, as shown in Table 1.

Table 1: Offshore Areas Under Country Jurisdiction

Area	Description	Legal Status
Territorial Sea	The waters and subsurface land extending 12 n.m. from the baseline.[253]	Forms part of the sovereign territory of the coastal state.[254]

[252] United Nations Convention on the Law of the Sea, Dec. 10, 1982, 1833 U.N.T.S. 397 [hereinafter UNCLOS]. UNCLOS has been ratified or otherwise adopted by 167 countries and the European Union. The U.S. has not ratified UNCLOS, but recognizes most of its provisions, including those discussed in Part 5.1.1. of this paper, as forming part of customary international law.

[253] *Id*. Art. 3.

[254] *Id.* Art. 2.

Area	Description	Legal Status
Exclusive Economic Zone ("EEZ")	The waters located adjacent to, and extending beyond, the territorial sea up to 200 n.m. from shore.[255]	The coastal state has: • sovereign rights to explore, exploit, conserve, and manage natural resources and undertake other activities for the economic exploitation of the EEZ; and • jurisdiction with regard to the establishment and use of artificial islands, installations and structures, marine scientific research, and marine protection in the EEZ.[256]

Continental Shelf	The submarine area located adjacent to, and extending beyond, the territorial sea to the farthest of:
	• 200 n.m. from the baseline; or
	• the outer edge of the continental margin[257] up to:
	  ○ 60 n.m. from the foot of the continental shelf; or
	  ○ the point where sediment thickness is 1 percent of the distance thereto,
	but not exceeding 100 n.m. from the 2,500 meter isobath or 350 n.m. from the baseline.[258]
		The coastal state has sovereign rights to explore and exploit the natural resources of the continental shelf.[259]

Except as noted in the table, countries generally do not have jurisdiction over areas more than 200 n.m. from shore, which form part of the high seas and are open to for use by all countries, both

[255] *Id.* Art. 55 & 57.
[256] *Id.* Art. 56.
[257] The "continental margin" refers to the submerged prolongation of the land mass of the coastal state. *See id.* Art. 76(1).
[258] *Id.* Art. 76(5).
[259] *Id.* Art. 77.

coastal and landlocked.[260] UNCLOS provides for "freedom of the high seas" which includes "(a) freedom of navigation; (b) freedom of overflight; (c) freedom to lay submarine cables and pipelines . . . ; (d) freedom to construct artificial islands and other installations . . . ; (e) freedom of fishing . . . ; [and] (f) freedom of scientific research."[261] Countries must exercise these freedoms "with due regard for the interests of other[s]."[262]

4.1.2 U.S. Jurisdictional Areas

Consistent with international law, the U.S. has claimed jurisdiction over all waters within 200 n.m. of its coast ("U.S. waters"), as well as the underlying submerged land.[263] Jurisdiction is shared among the coastal states and federal government. Under the Submerged Lands Act of 1953, the boundaries of each coastal state extend three n.m. from its coastline,[264] except in the Gulf of Mexico, where the boundaries of Texas and Florida extend nine n.m. from the coast.[265] Waters within that area ("state waters") fall under the primary jurisdiction of the relevant coastal state, though the federal government also some regulatory authority within state waters. Each coastal state has title to, and ownership of, all lands beneath its state waters and the natural resources (including minerals, marine animals, and plant life) within those lands and waters.[266]

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[260] *Id.* Art. 86-87. The seabed underlying the high seas, and the resources therein, are considered the "common heritage of mankind." Their development is overseen by the International Seabed Authority which must act on behalf of, and for the benefit of, mankind as a whole. *See id.* Art. 136-137, 140 & 150.

[261] *Id.* Art. 87(1).

[262] *Id.* Art. 87(2).

[263] Proclamation No. 5030, 48 Fed. Reg. 10605 (Mar. 14, 1983).

[264] 43 U.S.C. § 1312 (providing that "[t]he seaward boundary of each original coastal state is approved and confirmed as a line three geographic miles distant from its coast line"). *See also id*. § 1301(c) (defining a state's "coastline" as "the ordinary low water line along that portion of the coast which is in direct contact with the open sea").

[265] *Id*. § 1301(b) (defining the term "boundaries" and providing that "in no event shall the term boundaries . . . be interpreted as extending from the coast line more than three geographical miles in the Atlantic Ocean or the Pacific Ocean, or more than three marine leagues [i.e., nine nautical miles] into the Gulf of Mexico"). *See also* U.S. v. Louisiana, 100 S.Ct. 1619 (1980), 420 U.S. 529 (1975), 394 U.S. 11 (1969), 389 U.S. 155 (1967), 363 U.S. 1 (1960), 339 U.S. 699 (1950).

[266] 43 U.S.C. § 1311(a)(1). *See also id*. §§ 1301(a) (defining "lands beneath navigable waters" to include "all lands permanently or periodically covered by tidal waters up to but not above the line of mean high tide and seaward to a line three geographic miles distant from the coastline of each such State") & 1301(e) (defining "natural resources" to include, without limitation, "oil, gas, and all other minerals, and fish, shrimp, oysters, clams, crabs, lobsters, sponges, kelp, and other marine animals and plant life but does not include water power, or the use of water for the production of power").

Waters lying beyond state boundaries up to 200 n.m. from shore ("federal waters") fall under the exclusive authority of the federal government. The federal government has title to offshore land lying beneath those waters and, if the continental margin extends more than 200 n.m. from shore, additional land extending 60 n.m. from the food of the continental shelf or beyond the shelf foot to the point where the sediment thickness is one percent of the distance thereto (the "outer continental shelf" or "OCS").[267] The federal government does not, however, have title to any land located more than 350 n.m. from the baseline or 100 n.m. from the 2,500 meter isobaths (i.e., a line connecting the depth of 2,500 meters).[268]

4.2 Treatment of Sea-Based Enhanced Weathering Under International Law

There are currently no international agreements dealing specifically with sea-based enhanced weathering, but several agreements contain provisions that could apply to the activity. The most directly applicable are agreements governing the dumping of materials at sea, such as the 1972 Convention on the Prevention of Marine Pollution by Dumping of Waste and Other Matter ("London Convention"),[269] and the 1996 Protocol to that Convention ("London Protocol").[270] More general environmental agreements, such as those designed to prevent marine pollution and protect marine biodiversity, could also apply in some circumstances.

4.2.1 International Agreements Respecting Ocean Dumping

Under Article 210 of UNCLOS, countries have a general obligation to "prevent, reduce and control pollution of the marine environment by dumping."[271] That obligation is elaborated upon in the London Convention and London Protocol, which establish detailed rules with respect to the dumping of materials at sea.

[267] *Id*. § 1331 (defining the outer continental shelf to include "all submerged lands lying seaward and outside of the area of lands beneath [the] navigable waters [of a state]" which "are subject to [U.S.] jurisdiction" under international law. *See also* UNCLOS, *supra* note 252, Art. 76 (defining the limits of U.S. jurisdiction).
[268] UNCLOS, *supra* note 252, Art. 76(1), 76(4).
[269] Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter, Dec. 29, 1972 [hereinafter "London Convention"].
[270] Protocol to the Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matters, Nov. 7, 1996 [hereinafter "London Protocol"].
[271] UNCLOS, *supra* note 252, Art. 210(1). Countries must adopt laws, regulations, and other measures to "ensure that dumping is not carried out without the permission of the competent authorities of States." *See id*. Art. 201(3).

The London Convention was adopted in 1972 with the aim of "promot[ing] the effective control of all sources of pollution of the marine environment," particularly those resulting from the "dumping" of "waste or other matter" at sea.[272] Nations that are party to the London Convention must adopt domestic laws prohibiting the dumping of certain substances listed in Annex I to the Convention ("prohibited substances") and establishing a permitting regime through which the dumping of other (non-prohibited) substances may be authorized.[273] Given this, and since the list of prohibited substances contains only eight items, the London Convention is largely permissive of dumping.

Concerned that the London Convention may not adequately control dumping, in 1996, the parties adopted the London Protocol which is intended to update the Convention and will eventually replace it once ratified by all contracting parties.[274] The London Protocol sets more ambitious goals than the London Convention, aiming to "protect and preserve the marine environmental from all sources of pollution," and to "prevent, reduce and where practicable eliminate pollution caused by dumping."[275] Consistent with that aim, the London Protocol adopts a precautionary approach,[276] requiring parties to prohibit the dumping of all waste and other matter, with only limited exceptions.[277]

(A) Application of the London Convention and London Protocol to Enhanced Weathering

Both the London Convention and London Protocol define "waste and other matter" broadly to mean "material . . . of any kind, form or description" which would encompass the silicate materials used for enhanced weathering.[278] The London Convention and London Protocol will, however, only apply to enhanced weathering if the discharge of silicates into ocean waters constitutes "dumping" with the terms of those instruments. In both instruments, the term "dumping" is defined to mean the "deliberate disposal at sea of waste or other matter from vessels,

[272] London Convention, *supra* note 269, Art. I & II.
[273] *Id*. Art. IV.
[274] International Maritime Organization, *Convention on the Prevention of Marine Pollution by Dumping of Waste and Other Matter*, https://perma.cc/275E-QDYP (last visited Sep. 17, 2020)
[275] London Protocol, *supra* note 270, Art. 2.
[276] *Id*. Art. 3.
[277] *Id*. Art. 4. Parties to the London Protocol may only permit the dumping of wastes or other matter listed in Annex I to the Protocol.
[278] London Convention, *supra* note 270, Art. III.

aircraft, platforms or other man-made structures at sea."[279] Notably however, the definitions expressly exclude the "placement of matter for a purpose other than mere disposal thereof, provided that such placement is not contrary to the aims of" the London Convention or London Protocol (the "dumping exemption").[280] Thus, whether enhanced weathering constitutes dumping will turn on three key factors, namely:

(1) whether the discharge of silicates during enhanced weathering amounts to "disposal" of those materials (i.e., because the definition of dumping is tied to the disposal of waste or other matter);
(2) whether the silicates used in enhanced weathering constitute "waste" (i.e., because the dumping exemption only covers the "placement of *matter* for a purpose other than . . . disposal" (emphasis added) and not the placement of waste); and
(3) whether enhanced weathering is contrary to the aims of the London Convention or London Protocol (i.e., because the dumping exemption only applies where the placement of matter is not contrary thereto).

With respect to factor (1) above, the term "disposal" is not defined in the London Convention or London Protocol, but is generally used to refer to the act of getting rid of or discarding something that is no longer useful.[281] Applying that definition, enhanced weathering arguably does not involve disposal because it is not conducted for the purpose of getting rid of silicate materials, but rather to increase carbon sequestration and thus mitigate climate change.[282] In this respect, enhanced weathering is similar to ocean fertilization, which the parties to the London Convention and London Protocol have agreed constitutes a "placement of matter for a purpose other than mere disposal."[283] Both ocean fertilization and enhanced weathering involve discharging materials into ocean waters

[279] *Id*. Art. III(1)(a).
[280] *Id*. Art. III(1)(b)(ii).
[281] Cambridge Dictionary, *Disposal*, https://perma.cc/5PJN-5JZ8 (last visited Aug. 19, 2020). *See also*, Cambridge Dictionary, *Discard*, https://perma.cc/GN9C-V5ZP (last visited Aug. 19, 2020).
[282] *See generally*, Karen N. Scott, *Mind the Gap: Marine Geoengineering and the Law of the Sea, in* HIGH SEAS GOVERNANCE 34, 46 (Robert C. Beckman et al. eds., 2019) ("Although . . . weathering techniques involve the introduction of matter into the sea, it is not likely that the matter is 'disposed of,' given that its introduction is intended to serve a purpose"); Jesse L. Reynolds, *International Law, in* CLIMATE ENGINEERING AND THE LAW 57, 85 (Michael B. Gerrard & Tracy Hester eds., 2018) ("[T]he purpose of placing fertilizing or alkalinizing matter in the ocean . . . would not be *mere* disposal of those substances, but instead would be to indirectly remove carbon dioxide from the atmosphere").
[283] Resolution LC-LP.1(2008) on the Regulation of Ocean Fertilization, Art. 3 (Oct. 31, 2008) [hereinafter "2008 Resolution"].

to accelerate natural processes for removing carbon dioxide from the atmosphere[284] and should, therefore, be treated similarly for the purposes of the London Convention and London Protocol.[285]

With respect to factor (2) above, the term "waste" is also not defined in the London Convention or London Protocol, but is generally used to refer to worthless or superfluous materials, including by-products from manufacturing or industrial processes.[286] Many artificial silicates proposed for use in enhanced weathering, such as mine tailings and fly ash, are secondary products derived from industrial activities and thus may be considered waste for the purposes of the London Convention and London Protocol. It is, however, unlikely that ground silicate rock produced specifically for enhanced weathering would be treated as waste. The London Convention and London Protocol parties have previously determined that the materials used in ocean fertilization—i.e., manufactured fertilizers—constitute matter, rather than waste, for the purposes of those instruments.[287] Similarly to those materials, any ground silicate rock used for enhanced weathering would be produced specifically for that purpose, rather than as a by-product of other production processes.

Finally, with respect to factor (3) above, both the London Convention and London Protocol aim to protect the marine environment from pollution. As discussed in Part 2.2 above, enhanced weathering projects could negatively affect the marine environment, including by increasing water turbidity and/or introducing contaminants (e.g., heavy metals) into the water. While there is significant uncertainty regarding the extent of any potential adverse impacts, given the precautionary approach adopted in the London Protocol, enhanced weathering is likely to be considered contrary to the aims of that instrument. It may also be considered contrary to the aims of the London Convention, even though that instrument does not expressly adopt a precautionary approach. Here, again, the parties' approach to ocean fertilization is instructive.

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[284] In ocean fertilization, iron or other nutrients are added to ocean waters to stimulate the growth of phytoplankton, which increases photosynthesis, leading to the removal of additional carbon dioxide from the atmosphere. *See generally*, Phillip Williamson et al., *Ocean Fertilization for Geoengineering: A Review of Effectiveness, Environmental Impacts and Emerging Governance*, 90 PROCESS SAFETY & ENVIRONMENTAL PROTECTION 475 (2012).

[285] *See generally*, Brent et al., *supra* note 49, at 38 (Like ocean fertilization, enhanced weathering "involves placement of matter into the ocean for a purpose other than mere disposal").

[286] Merriam-Webster Dictionary, *Waste*, https://perma.cc/Z65T-EJ7S(last visited Aug. 19, 2020).

[287] 2008 Resolution, *supra* note 283, Art. 3.

In 2008 the parties agreed that, given uncertainties regarding its "effectiveness and potential environmental impacts," ocean fertilization conducted other than as part of legitimate scientific research "should be considered contrary to the aims of the [London] Convention and [London] Protocol."[288] The parties agreed that scientific research projects should be assessed on a case-by-case basis and, in 2010, adopted a framework to guide that assessment.[289] Under the framework, scientific research projects will be considered contrary to the aims of the London Convention and London Protocol, unless "conditions are in place to ensure that, as far as practicable, environmental disturbance would be minimized, and the scientific benefits maximized."[290] Given the similarities between ocean fertilization and enhanced weathering, the parties are likely to adopt a similar approach to the latter.

As the foregoing discussion shows, while enhanced weathering is unlikely to be considered "disposal" for the purposes of the London Convention and London Protocol, in at least some cases, the materials used may constitute "waste" and thus fall outside the scope of the dumping exemption. Even where this is not the case, the dumping exemption will only apply if enhanced weathering is found not to be contrary to the aims of the London Convention and London Protocol, which must be assessed on a case-by-case basis. Where a particular enhanced weathering project presents a high risk of harm to the environment, and delivers few or unknown benefits, it is likely to be considered contrary to the aims of the London Convention and London Protocol.[291] Such projects would not, therefore, qualify for the dumping exemption.

(B) Requirements Imposed by the London Convention and London Protocol

Enhanced weathering projects that do not qualify for the dumping exemption will be subject to the London Convention or London Protocol if performed:

(1) in the territorial sea or EEZ of a party to the Convention or Protocol; or

[288] *Id*. Preamble & Art. 8.

[289] *Id*. Art. 4-5.

[290] Resolution LC-LP.2(2010) on the Assessment Framework for Scientific Research Involving Ocean Fertilization, Annex 6 (Oct. 14, 2010).

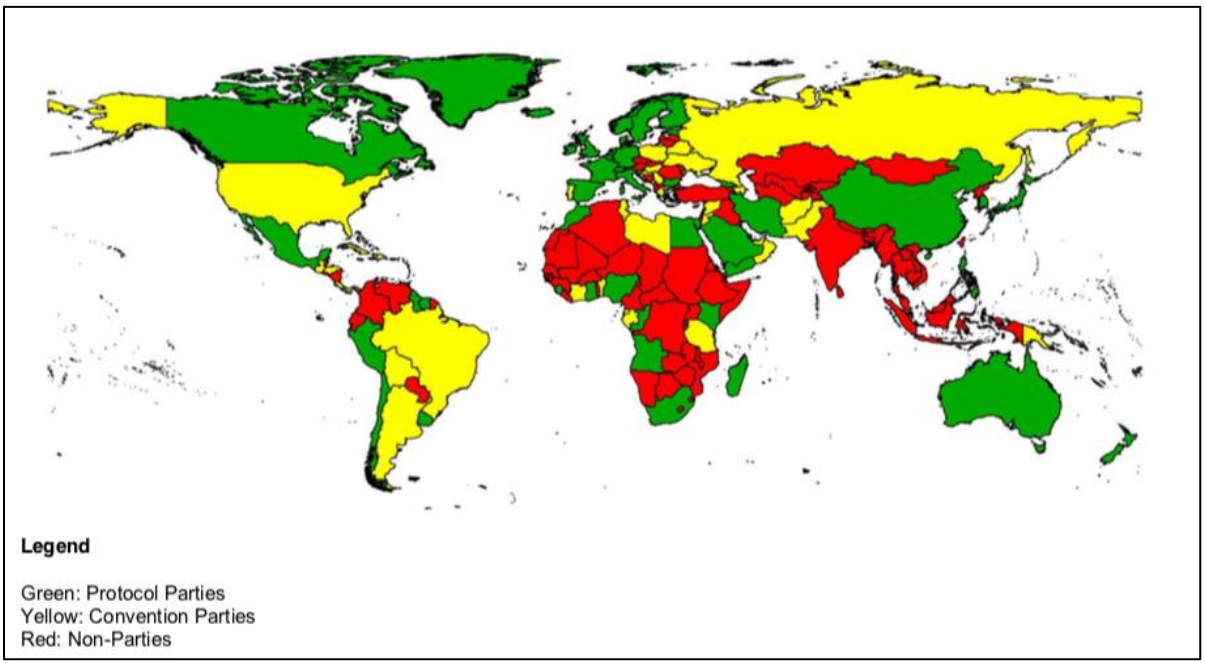
[291] *See generally*, Brent et al., *supra* note 49, at 38 (concluding that "[l]arge-scale field tests and full-scale deployment [of enhanced weathering] activities will almost undoubtedly qualify as dumping because they are likely to present risks of harm to the marine environment. Small-scale research activities may be exempt from this definition if they do not present risks to the marine environment").

(2) using a vessel or aircraft that is registered, or was loaded, in the territory of a party (i.e., regardless of where the enhanced weathering occurs).[292]

At the time of writing, there were eighty-seven parties to the London Convention, and forty-five parties to the London Protocol (see Figure 2).[293] For countries that are party to both instruments, the London Protocol supersedes the London Convention.

The London Convention and London Protocol impose different requirements with respect to the regulation of enhanced weathering. As discussed in Part 4.1.1(A) above, the London Convention establishes a more permissive regulatory regime, under which parties may authorize

Figure 2: Parties to the London Convention and London Protocol[294]



[292] London Convention, *supra* note 269, Art. VI (requiring each party to the London Convention to apply the measures therein "to all (a) vessels and aircraft registered in its territory or flying its flag; (b) vessels and aircraft loading in its territory or territorial sea which is to be dumped; (c) vessels and aircraft and fixed or floating platforms under its jurisdiction believed to be engaged in dumping"); London Protocol, *supra* note 270, Art. 10.1 (requiring each party to the London Protocol to "apply the measures required to implement th[e] Protocol to all .1 vessels and aircraft registered in its territory or flying its flag; .2 vessels and aircraft loading in its territory the wastes or other matter which are to be dumped . . . at sea; and .3 vessels, aircraft and platforms or other man-made structures believed to be engaged in dumping . . . in areas within which it is entitled to exercise jurisdiction in accordance with international law").

[293] International Maritime Organization, *Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter*, https://perma.cc/275E-QDYP (last visited Sep. 17, 2020). The U.S. is a party to the London Convention only. The U.S. signed, but never ratified, the London Protocol.

[294] International Maritime Organization, *Map of Parties to the London Convention/Protocol*, https://perma.cc/XYE4-SQYK (last updated Feb. 22, 2019).

the dumping of all materials, except the prohibited substances listed in Annex I to the Convention.[295] The silicate rocks proposed for use in enhanced weathering are not prohibited substances under Annex I.[296] Artificial silicates may be, however. The list in Annex I includes "industrial waste," defined as "waste materials generated by manufacturing or processing operations."[297] That definition is likely to encompass artificial silicates in the form of mine tailings, fly ash, iron and steel slag, and cement kiln dust, all of which are waste materials generated during the manufacture or processing of other products. Parties to the London Convention could, therefore, only permit enhanced weathering using natural silicates and not artificial ones. The London Protocol is even more restrictive.

Unlike the London Convention, the London Protocol requires parties to prohibit the dumping of all materials, except those listed in Annex I to the Protocol. Since that list does not include any silicate materials (either natural or artificial), the London Protocol effectively prohibits enhanced weathering at sea. In order to remove the prohibition, Annex I to the London Protocol would need to be amended to include the silicate materials used for enhanced weathering. At the time of writing, no such amendment had been proposed. The parties have, however, adopted an amendment dealing with certain related activities.

In 2013, the parties to the London Protocol adopted an amendment to regulate specified marine geoengineering activities.[298] The amendment, which has not yet entered into force,[299] defines "marine geogeneering" as any "deliberate intervention in the marine environment to manipulate

[295] London Convention, *supra* note 269, Art. IV(1).

[296] The materials used in enhanced weathering may include trace amounts of certain substances listed in Annex I to the London Convention. That will not, however, affect the ability of parties to the London Convention to permit enhanced weathering. The London Convention expressly states that the prohibition on dumping listed substances "does not apply to wastes or other materials containing [listed substances] as trace elements." *See id*. Annex I(9).

[297] *Id*. Annex I(11).

[298] Resolution LP.4(8) on the Amendment to the London Protocol to Regulate the Placement of Matter for Ocean Fertilization and Other Marine Geoengineering Activities (Oct. 18, 2013) [hereinafter "2013 Amendment"].

[299] International Maritime Organization, *London Convention (LDC.LC) and London Protocol*, INDEX OF IMO RESOLUTIONS, https://perma.cc/C65C-2P87 (last updated Oct. 16, 2018). For the 2013 amendment to enter into force, it must be ratified by two-thirds of the 53 parties to the London Protocol. *See* London Protocol, *supra* note 270, Art. 21(3). As of April 2017, only one party (i.e., the United Kingdom) had ratified the amendment. *See* Scott, *supra* note 282, at 50.

natural processes, including to counteract anthropogenic climate change and/or its impacts, and . . . [have] the potential to result in deleterious effects, especially where those effects may be widespread, long lasting or severe."[300] Under the amendment, parties must not allow the placement of matter into the sea for any listed marine geoengineering activity, unless the listing provides that the activity or a subcategory thereof may be authorized under a permit.[301] As currently drafted, the amendment only lists ocean fertilization, and provides that "all ocean fertilization activities" must be prohibited, except those involving "legitimate scientific research."[302] While the amendment does not expressly apply to enhanced weathering, given its similarities to ocean fertilization, the London Protocol parties are likely to take a similar approach to both practices, allowing scientific research but not commercial-scale projects.[303]

4.2.2 Other Potentially Applicable International Agreements

In addition to the London Convention and London Protocol, various other international agreements could also apply to enhanced weathering at sea. Several agreements require parties to take steps to avoid or mitigate environmental harms, such as pollution, which sea-based enhanced weathering could result in. Under Article 194 of UNCLOS, for example, parties must take all necessary measures to "prevent, reduce and control pollution of the marine environment."[304] Pollution is defined broadly to mean:

> the introduction by man, directly or indirectly, of substances or energy into the marine environment, including estuaries, which results or is likely to result in such deleterious effects as harm to living resources and marine life, hazards to human health, hindrance to marine activities, including fishing and other legitimate uses of the sea, impairment of quality for use of the sea water and reduction of amenities.[305]

Applying this definition, enhanced weathering could be considered a form of marine pollution because it involves the introduction of silicates into ocean waters, which could harm the marine environment (e.g., by increasing the turbidity of, or introducing contaminants into, the water). As the risk of harm is likely to vary between projects, a case-by-case assessment should be

[300] 2013 Amendment, *supra* note 298, Art. 1(5)*bis*.
[301] *Id*. Art. 6(1)*bis*.
[302] *Id*. Annex 4.
[303] *See supra* Part 5.2.1.1.
[304] UNCLOS, *supra* note 252, Art. 194(1).
[305] *Id*. Art. 1(1)(4).

undertaken.[306] The assessment should consider not only the risks posed by the project but also its likely effectiveness in sequestering carbon dioxide and thus mitigating climate change.[307] This is relevant because carbon dioxide and climate change also constitute pollution for the purposes of UNCLOS.[308]

If an enhanced weathering project were found to involve pollution of the marine environment, UNCLOS would require the party under whose jurisdiction it occurs to:

- take all necessary measures to minimize the adverse impacts of the project and ensure that it does not cause damage to other states or their environments;[309]
- notify affected countries and competent international authorities of any imminent or actual damage from the project;[310] and
- study the risks and effects of the project and publish the results of that study.[311]

Countries also have additional obligations under the CBD which, as discussed in Part 3 above, aims to promote "the conservation of biological diversity, [and] the sustainable use of its components."[312] Article 7 of the CBD requires parties to, "as far as possible and as appropriate," identify projects "which have or are likely to have significant adverse impacts on the conservation and sustainable use of biological diversity, and monitor their effects."[313] Under Article 14 of the CBD, parties must require environmental impact assessments of the projects, "with a view to avoiding or minimizing [their] adverse effects."[314] For projects that could have transboundary effects, parties must "[p]romote . . . notification, exchange of information and consultation" with potentially affected countries.[315] In the case of "imminent or grave" transboundary damage, parties must "notify immediately the potentially affected" countries, and "initiate action to prevent or minimize" any

[306] Reynolds, *supra* note 282, at 77.
[307] *Id*.
[308] *Id*. at 76 (asserting that "GHGs and probably global warming qualify under UNCLOS as pollution of the marine environment"). *See also id*. at 78 (discussing the need to "balance . . . the deleterious impacts of climate change, the potential for climate engineering to reduce these impacts, and climate engineering's own risk").
[309] UNCLOS, *supra* note 252, Art. 194 & Art. 196. *See also id.* Art. 208-209 & 211-212.
[310] *Id*. Art. 198.
[311] *Id*. Art. 204-206.
[312] CBD, *supra* note 68, Art. 1.
[313] *Id*. Art. 7(c).
[314] *Id*. Art. 14(1)(a).
[315] *Id*. Art 14(1)(c).

damage.[316] Parties should also have in place "arrangements for emergency responses" to projects that represent a "grave and imminent danger to biological diversity" within their own territory.[317]

Provided the above requirements are met, the CBD would not prevent countries undertaking or authorizing enhanced weathering projects, even if such projects adversely affect biodiversity.[318] Nevertheless, the Conference of the Parties to the CBD has recommended that such projects be avoided "until there is in place an adequate scientific basis on which to justify" them, and their environmental, social, economic, and cultural impacts have been appropriately considered.[319] That recommendation is non-binding, however.

4.3 Treatment of Sea-Based Enhanced Weathering Under U.S. Law

The U.S. is a party to just one of the above international agreements—the London Convention which it ratified in April 1974.[320] The London Convention is implemented domestically through the Marine Protection, Research, and Sanctuaries Act ("MPRSA"), which regulates "the dumping of all types of materials into ocean waters" within twelve n.m. of the U.S. coast and further in some circumstances.[321] While the MPRSA does not specifically address sea-based enhanced weathering, the practice is likely to be treated as a form of dumping for the purposes of the Act.

Compared to the London Convention, the MPRSA adopts a broader definition of "dumping," which includes any "disposition of material."[322] The term "material" is also defined

[316] *Id*. Art 14(1)(d).
[317] *Id*. Art. 14(1)(e).
[318] The CBD applies to all activities carried out under the jurisdiction or control of a party thereto, regardless of whether they occur within or beyond the area under the party's national jurisdiction. *See id*. Art. 4(b).
[319] Report of the Conference of the Parties to the Convention on Biological Diversity on the Work of its Eleventh Meeting, Decision XI/20, Art. 6-9 (2012).
[320] U.S. Envtl. Prot. Agency, *Ocean Dumping: International Treaties*, OCEAN DUMPING, https://perma.cc/UX3F-EM7H (last updated Feb. 29, 2019).
[321] 33 U.S.C. § 1401(b)
[322] *Id*. § 1402(f). There are several exceptions to the definition for: (1) "a disposition of any effluent from any outfall structure to the extent that such disposition is regulated under the provisions of the Federal Water Pollution Control Act . . . . or under the provisions of the Atomic Energy Act of 1954;" (2) "a routine discharge of effluent incidental to the propulsion of, or operation of motor-driven equipment on, vessel;" (3) "the construction of any fixed structure or artificial island []or the intentional placement of any device in ocean waters or on or in the submerged lands beneath such waters, for a purpose other than disposal, when such construction or such placement is otherwise regulated by Federal or State law or occurs pursuant to an authorized Federal or State program." None of those exceptions will apply to the discharge of materials for enhanced weathering.

broadly to mean "matter of any kind or description."[323] Applying those definitions, the silicates used in enhanced weathering would constitute "material" and their discharge into ocean waters would constitute "dumping" for the purposes of the MPRSA.

In general, and with some exceptions, the MPRSA prohibits the dumping of materials into ocean waters without a permit from EPA. Enhanced weathering projects would need to be permitted where:

- the silicate materials to be discharged into ocean waters are transported from within the U.S. (regardless of where the discharge occurs);[324] or
- the materials are transported from outside the U.S. and:
    - transportation occurs on a vessel registered in the U.S. (regardless of where the discharge occurs); or
    - the discharge occurs within twelve n.m. of the U.S. coast (regardless of how the silicates are transported).[325]

Under the MPRSA, EPA cannot permit the dumping of industrial waste, which is defined as "any soil, semi-solid, or liquid waste generated by a manufacturing or processing plant."[326] That definition would likely encompass artificial silicates in the form of mine tailings, fly ash, iron and steel slag, and cement kiln dust.[327] Enhanced weathering using artificial silicates is, therefore, effectively prohibited under the MPRSA. Enhanced weathering could, however, be performed using ground silicate rock with a permit from EPA.

EPA can only issue permits under the MPRSA if satisfied that the discharge of materials into ocean waters "will not unreasonably degrade or endanger human health, welfare, or amenities, or the marine environment, ecological systems, or economic potentialities."[328] Dumping can only occur in EPA-designated dump sites, which are chosen to mitigate the adverse impacts of dumping on the

[323] *Id*. § 1402(c).
[324] *Id*. § 1411(a)(1) (prohibiting any person transporting material from the U.S. for the purpose of dumping it into ocean waters). *See also id*. § 1402(b) (defining "ocean waters" to mean "those waters of the open seas lying seaward of the baseline from which the territorial sea is measured").
[325] *Id*. § 1411(a)(2) & (b).
[326] *Id*. § 1414b
[327] *See supra* Part [4.2.1.2].
[328] 33 U.S.C. § 1412(a).

environment, as well as the extent to which it interferences with other activities.[329] At the time of writing, there were ninety-eight dump sites.[330] Ninety-seven of those sites were approved only for the dumping of dredged material (i.e., removed from beneath navigable waters) and one only for the dumping of fish processing wastes.[331] None of the sites could, therefore, be used for enhanced weathering projects.

Persons wanting to engage in enhanced weathering could apply to EPA for designation of a new dump site or approval to use an existing site.[332] On receiving an application, EPA will evaluate the physical, chemical, and biological characteristics of the site, as well as the impacts of past dumping in areas with similar characteristics, to determine whether it is suitable for use.[333] EPA must also conduct an environmental review under NEPA[334] and consult with various federal and state bodies as required under:

- Section 7 of the ESA, which requires federal agencies to consult with the National Marine Fisheries Service about any activity that could affect endangered or threatened marine species or their habitat.[335]
- Section 305 of the Magnuson-Stevens Fishery Conservation and Management Act, which requires federal agencies to consult with the National Marine Fisheries Service before conducting, authorizing, or funding any action that may adversely affect waters designated as "essential fish habitat."[336]

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[329] *Id*. § 1412(c); 40 C.F.R. § 228.5.
[330] Envtl. Prot. Agency, *Ocean Disposal Map*, OCEAN DUMPING, https://perma.cc/XG2L-UYLG (last updated Nov. 4, 2019).
[331] Envtl. Prot. Agency, *Ocean Disposal Sites*, OCEAN DUMPING, https://perma.cc/L6GM-DXAA (last updated Nov. 4, 2019).
[332] 40 C.F.R. § 221.1(f).
[333] *Id*. §§ 228.4 & 228.6.
[334] 42 U.S.C. § 4321 et seq. NEPA requires federal agencies to prepare an environmental impact statement (EIS) in relation to any major federal action that "significantly affect[s] the quality of the human environment." *See id*. § 4332(2)(C). That requirement has been held not to apply to actions taken under the MPRSA, but EPA voluntarily conducts a NEPA review when designating sites pursuant to the Act. *See* Policy and Procedures for Voluntary Preparation of National Environmental Policy Act (NEPA) Documents, 63 Fed. Reg. 58045, 58046 (Oct. 29, 1998).
[335] 16 U.S.C. § 1563(a)(1). A species is considered "endangered" if it "is in danger of extinction throughout all or a significant portion of its range." *See id*. § 1532(6). A species is "threatened" if it "is likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range." *See id*. § 1532(20).
[336] *Id*. § 1855(b)(2).

- Section 307 of the Coastal Zone Management Act, which requires federal agencies to ensure that any actions affecting land or water use or natural resources within the boundaries of a coastal state (i.e., typically three nautical miles from shore) are performed in a manner consistent with any applicable state coastal management plan to the maximum extent practicable.[337] The federal agency must provide the state with a "consistency determination," which describes the action and its expected effects, and explains how it is consistent with the state coastal management plan.[338] If the state objects, the federal agency must work with it to address the objection.[339]

Once EPA designates an area as a dump site, it may permit the dumping of materials therein. Permits are issued by the relevant EPA regional office, which must consider "the environmental effect of the proposed dumping operation, the need for ocean dumping, alternatives to ocean dumping, and the effect of [dumping] on esthetic, recreational and economic values and on other uses of the oceans."[340]

4.4 Potential Liability for Damage Caused by Sea-Based Enhanced Weathering Projects

Countries that conduct or authorize sea-based enhanced weathering projects that cause environmental damage could be liable under in international law in some circumstances. As discussed in Part 4.2.2 above, countries that are party to UNCLOS have a general obligation to avoid "pollution of the marine environment"[341] and, to that end, must evaluate and take steps to mitigate any adverse effects from projects they conduct or authorize.[342] UNCLOS declares that, where a party fails to fulfil these requirements, it "shall be liable in accordance with international law."[343] The relevant principles of international law were summarized in a resolution adopted by the United Nations General Assembly in December 2001.[344] The resolution provides that, where a country breaches an international obligation and that breach causes harm to another, the former must cease

[337] 16 U.S.C. § 1456(c).
[338] *Id*. § 1456(c)(1)(C); 15 C.F.R. § 930.39.
[339] 40 C.F.R. § 930.34.
[340] *Id*. § 227.1.
[341] UNCLOS, *supra* note 252, Art. 194.
[342] *Id.* Art. 194, 196, 198, & 204-206.
[343] *Id*. Art. 235(1).
[344] Resolution Adopted by the United Nations General Assembly, Responsibility of States for Internationally Wrongful Acts, A/RES/56/83 (Jan. 28, 2002) [hereinafter "UN Resolution on State Responsibility"].

the offending conduct and "offer appropriate assurances and guarantees of non-repetition."[345] The country must also make "full reparation" for any injuries caused by its conduct through restitution (i.e., action to re-establish the status quo ante), compensation (i.e., payments to cover any "financially assessable damage"), or satisfaction (i.e., "an acknowledgement of the breach, an expression of regret, a formal apology," or similar statement).[346]

While the U.S. is not a party to UNCLOS, many of the Convention's provisions, including those dealing with marine pollution, have been held to form part of customary international law.[347] Thus, for example, customary international law requires the U.S. to take appropriate steps to minimize pollution and other environmental harms from sea-based enhanced weathering projects. If the U.S. failed to fulfil that requirement and a project caused injury to others, it would be liable to make reparations to the injured party, unless a defense were available. Customary international law recognizes a defense of "necessity," which is available where a country acts to "safeguard an essential interest against a grave and imminent peril."[348] Some legal scholars have argued that the risks posed by climate change are sufficiently "grave and imminent" to justify enhanced weathering and similar projects as acts of necessity.[349] Notably, however, the necessity defense cannot be invoked by a country that has itself "contributed to the situation of necessity."[350] The U.S. is the leading historic contributor to climate change, having the highest cumulative greenhouse gas emissions of any country, and thus may be unable to rely on the necessity defense.

As well as exposing the U.S. to potential liability under international law, sea based enhanced weathering projects could also expose private parties to liability under domestic law. For example, if an enhanced weathering project interfered with the use of U.S. waters, the project

[345] *Id*. Art. 30. *See also id*. Art. 2 (specifying when a country will be considered to have committed a "wrongful act").
[346] *Id*. Art. 31 & 34. *See also id*. Art. 35 (defining "restitution"), Art. 36 (defining "compensation"), & Art. 37 (defining "satisfaction").
[347] *See generally*, Scott, *supra* note 282, at 42-34.
[348] *Id*. Art. 25(1)(a).
[349] *See e.g.,* Reynolds, *supra* note 282, at 120 (arguing that "[f]or countries such as small island states that could face existential risks form climate change, necessity might operate as a legal preclusion from wrongfulness for climate engineering activities that would otherwise be contrary to international law").
[350] UN Resolution on State Responsibility, *supra* note 344, Art. 25(2)(b).

developer could be subject to an action for public nuisance.[351] However, as discussed in Part 3.3 above, the developer may be able to argue that the project's benefits outweigh its risks.

5. CONCLUSION

Deep across the board cuts in greenhouse gas emissions are essential to limit further temperature increases and thus avert the worst impacts of climate change. However, with global average temperatures already 1°C above pre-industrial levels and expected to hit 1.5°C within the next decade, simply cutting future greenhouse gas emissions may not be enough. It may also be necessary to remove previously-emitted greenhouse gases from the atmosphere. Scientists have proposed a number of greenhouse gas removal techniques, many of which aim to accelerate natural processes that already occur as part of the earth's climate cycle. One example is enhanced weathering which involves spreading ground silicate rocks or other materials with similar chemical composition over land or ocean waters so as to accelerate natural mineral weathering processes.[352] Research suggests that enhanced weathering could remove and store large amounts of carbon dioxide from the atmosphere.[353] However, questions remain about the risks posed by enhanced weathering, including the potential for re-release of the captured carbon dioxide back into the atmosphere.[354]

There are also significant questions regarding how enhanced weathering projects will be regulated. There are currently no international or U.S. federal or state regulatory programs specific to enhanced weathering on land or at sea. As discussed in this paper, however, projects could be regulated under various general environmental and other programs.[355] At the international level, potentially applicable instruments include the CBD, UNCLOS, and the London Convention and Protocol.[356] Domestically, projects could be subject to various provisions of the CAA, CWA, RCRA,

[351] *See infra* Part 3.3.
[352] *See supra* Part 2.1.
[353] Strefler et al., *supra* note 17, at 4 (estimating that applying ground rock to all suitable croplands globally could sequester up to 956 gigatons of carbon dioxide could be sequestered annually).
[354] National Academies, *supra* note 12, at 3-4.
[355] This paper surveyed key international and U.S. federal and state laws applicable to the performance of enhanced weathering projects on land or in ocean waters. Laws applicable to the sourcing of materials for use in such projects are dealt with in a separate (forthcoming) paper by the author.
[356] *See supra* Parts 3 and 4.2.

and MPRSA, among other statutes.[357] Exactly when and how these statutes will apply remains uncertain. Much will depend on the specific design of each project, including where it is conducted, the materials used, and how they are applied to land or ocean waters.

[357] *Id*.