

# Salt Lines: Markers of Climate Change

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**Abstract**

*A critical side-effect of climate change and the connected sea level rise is the migrating, in rivers that flow to the sea, of the salt line, namely the area where fresh water becomes salty. The movement of the salt line up the rivers can affect the supply of fresh water, with deep impacts on communities and economic activities, as well as animal and vegetal species. The article discusses the possible and still not entirely known effects of the salt line movement in three cases – the Hudson and the Delaware rivers in North America, and the Clyde river in Europe – and wonders how salt lines could be represented, that is part of the larger challenge of understanding and visualizing the climate change phenomenon.*

**Keywords**

*Climate change, salt lines, rivers, representation.*

We map our territories with lines. These marks imply permanence; here a road, there a river. In rivers that flow to the sea, there is a place where fresh water becomes salty. We call this place the salt line or the salt front. The salt line is defined as the place where water reaches the 250 milligram per liter chloride concentration point. This place has consequences for our own survival as well as for the habitat of other species. This line can move up or down a river with changing flows and water demands. Rising sea levels can increase the salinity in both the groundwater and surface waters.

Salt lines are in greater flux with global warming and sea level rise. How might we represent such change? In this essay, we explore ways of representing, of drawing, salt lines. We focus on two North American rivers (the Hudson and the Delaware) as well as one in Europe (the Clyde). All three flow into the Atlantic, provide vast waters, and are home for many species. How might the movement of the salt line up these rivers affect our supplies of fresh water? How may they impact other species, for instance, the migration of the magnificent American shad or the majestic Atlantic salmon returning again to the Clyde?

The Hudson and the Delaware had thriving Native-American communities prior to European colonization. The Lenni-Lenape (who were renamed the

Delaware by the English) dominated the lower Hudson and Delaware valleys. The areas were rich territories to farm, hunt, and fish. The estuaries of these rivers, where fresh water met salt, were especially important for fishing and harvesting oysters. These once-thriving peoples were decimated after the invasion of Europeans by warfare and disease.

The Dutch, Swedish, and English explored these rivers and found them ideal locations for settlements. They adapted Native-American farming techniques and crops while introducing new species. After native people were killed and displaced, new towns were established on previously settled locations and new roads followed well-traveled paths. The Europeans found ideal locations for port cities, notably New Amsterdam (later New York) and Philadelphia. These cities, central to the history of the United States, became portals for ever-growing immigration and powerful centers of trade, commerce, and innovation.

The history of the River Clyde is older than its American counterparts. People have lived along the Clyde for millennia and there have been organized settlements at current-day Glasgow since at least Roman times. Saint Mungo established a church at Glasgow in the 6<sup>th</sup> century and subsequently the city grew from a small rural settlement to a major center for trade, manufacturing, and textiles. The



Glasgow region became especially well-known for shipbuilding as did the Delaware Valley, which became known as 'the American Clyde' (Taylor, 2012). Clyde shipbuilding grew more pronounced during the early 20th century, with massive output during the First and Second World Wars. This was followed by decline beginning in the 1960s. We couple descriptions of the drainages of these rivers with accounts about the threats posed by migrating salt lines due to climate change.

### The Hudson

The headwaters of the Hudson are in the Adirondack Mountains of upstate New York. The river flows south for 315 miles (507 km) into New York Bay between New York City and Jersey City before draining into the Atlantic Ocean. Its drainage basin encompasses 14,000 square miles (36,000 km<sup>2</sup>). Named for the English explorer Henry Hudson (who sailed for the Dutch), much of the lower part of the river is a tidal estuary. Its salt line varies with the

tides and weather from Poughkeepsie in the north to Battery Park in the south but is usually located near Newburgh.

Federal, state, and local officials are studying the movement of the salt front and the consequences for water supplies and wildlife habitat. The U.S. Geological Survey (USGS), in cooperation with the State of New York, has observed:

The effect of major freshwater withdraws on the salinity in the transition zone of the Hudson River is unknown. Increased salinity and upstream movement of the salt front could adversely affect wildlife habitats and water supplies. As a result, new water supplies cannot be developed until their probable effect on saltwater movement can be determined. (USGS 2019)

As a result, the USGS and New York State are identifying and analyzing the drivers that determine the location and the shape of the Hudson salt line. This work will help identify the effects of seasonal variations and forecast the likely effects.

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**Fig. 1** – George Innes (1825-1894), *The Delaware Water Gap*, about 1857, oil on canvas, 90.5 x 138.5 cm, National Gallery of Art, London.

## The Delaware

The Delaware begins in two primary branches in the Catskill Mountains of New York. The river flows south for 388 miles (624 km) between New York and Pennsylvania, then between Pennsylvania and New Jersey, and then between New Jersey and Delaware into the Delaware Bay before draining into the Atlantic. Its drainage basin covers 14,119 square miles (36,570 km<sup>2</sup>). The native people called it the Lenapewihittuk and the Kithanne. The first European to explore the river was again Henry Hudson. These people and their river were renamed for Thomas West, the third Baron De La Warr. William Penn founded Philadelphia below the fall line of the Delaware, which is located at Trenton, New Jersey. The fall line runs across the city of Philadelphia to the Schuylkill ('hidden creek' in Dutch) River. The normal salt line of the Delaware fluctuates with the tides and weather below Wilmington and has moved north as far as Philadelphia during drought. As the salt line is creeping northward with climate change, it is being monitored by, among others, by the Delaware River Basin Commission (DRBC), comprised of federal and state agencies. The DRBC regulates water supply in the basin portions of New Jersey, New York, Pennsylvania, and Delaware. One concern is the drinking water intakes for the City of Philadelphia. If the salt line were to reach those

intakes, the drinking water of millions of people would be at risk.

In times of drought, DRBC uses releases from upstream reservoirs to prevent the salt front from moving up the Delaware (Hurdle, 2016). In such periods, residents and businesses have been urged to conserve water. But what happens when droughts, floods, and sea surges become more frequent?

A 2008 urban design studio at the University of Pennsylvania Stuart Weitzman School of Design addressed this question. The studio found that climate change coupled with projected urban growth "could place 1.4 million residents, 147,000 jobs, and \$20.4 billion of residential property" in jeopardy (University of Pennsylvania, 2008, p. 10). This study focused on sea level rise, flooding, and storm surge in addition to salinity as all four phenomena are interrelated. The studio report documents how the lower Delaware's estuarine and saline fringes will eventually become open water (University of Pennsylvania, 2008). These tidal marshes help to protect upland areas from storm surges and are rich wildlife habitats. Since the 1970s, the lower Delaware has experienced a dramatic transformation as pollution has been much reduced as a result of clean water laws. Similar action is needed to mitigate the impacts of climate change.



## The Clyde

From its origins in the moorlands of the Scottish Southern Uplands, the River Clyde flows north-westward around 106 miles (170 km) before draining into the Firth of Clyde and then the Atlantic. Before reaching its mouth, the Clyde drains some 1,500 square miles (4,000 km<sup>2</sup>). Along the way, at the Falls of Clyde, the river drops 250 feet (25 m) in four miles (24km), providing water power important for the location of cotton mills in the early 19<sup>th</sup> century during the Industrial Revolution. The origin of the name Clyde is in the Old Celtic, possibly meaning 'cleanse' and also possibly the name of a river goddess. The Roman historian Tacitus refers to the river as the *Clota*.

Climate change is affecting the Clyde. In a report comprehensive review of the Firth of Clyde (also the Clyde Sea) ecosystems, the Scottish government observed:

The Clyde ecosystem is one that has been used by humans for centuries, and hence it is changed. But humans can also now influence the direction the ecosystem takes by managing human activities in the future, precisely because the Clyde is not an ecological desert, but is an active ecosystem with great potential for future sustainable use. (McIntyre et al. 2012, p. 5)

Furthermore, the same authors noted:

There is increasing evidence and agreement within the scientific community that the release of greenhouse gases into the atmosphere is the major cause of the observed average increase in global temperatures over the last century. Around the coast of Scotland an increase in sea temperatures has been observed which has the potential to alter the abundance and distribution of marine species. Marine Scotland currently maintains a network of coastal temperature monitoring stations around the coast of Scotland... Recent analysis of temperature data from the sites currently monitored in the inshore areas show that the Clyde Sea may be warming faster than coastal waters within the North Sea. (McIntyre et al. 2012, p. 32)

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**Fig. 2** – River Clyde, Helensburgh, Scotland, 2019  
(photo by Frederick Steiner).

## Prospects

With climate change, the salt lines of these three rivers and many more are changing. One challenge we face is how to visualize what is currently invisible. The quest for ways to represent salt lines is part of a larger challenge of climate change. People relate to weather: a blizzard, a hot afternoon, a thunderstorm. Climate is more abstract. Climate scientists study the patterns of temperature, humidity, wind, and precipitation. From its ancient Greek root, *klima*, climate is weather averaged over long time periods. We can see and feel weather, we do not experience or see averages. As a result, we need ways to understand and visualize changing averages.

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