
THE ORDER
1886™
ReadyatDawn
STUDIOS

Crafting a Next-Gen Material Pipeline for The Order: 1886

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About Our Project

- Brand-new IP
- Alternate history 19th-century London
- Exclusive to PlayStation 4
- In-house engine
- ~80 developers

Core Shading Model

- Default specular BRDF is Cook-Torrance
  - D term is GGX distribution from Walter et al.
  - Matching Smith G term derived in same paper
  - Schlick's approximation for Fresnel
  - Lambertian diffuse, balanced with specular intensity

Core Shading Model

- Other BRDFs available
  - Beckmann (also taken from Walter et al.)
  - Anisotropic GGX
  - Hair (Kajiya-Kay)
  - Skin (pre-integrated diffuse)
  - Cloth

Skin shading

Pre-integrated skin diffuse with SH

$$D(\theta, r) = \frac{\int_{-\pi}^{\pi} \cos(\theta + x) R(2r \sin(x/2)) dx}{\int_{-\pi}^{\pi} R(2r \sin(x/2)) dx}$$

$$D_n(r) = 2\pi \int_0^{\pi/2} Y_{n,0}(\theta) D(\theta, r) sin(\theta) d\theta$$

$$f_{skinSH}(\mathbf{n}, r) = \sum_{l=0}^{2} \sum_{m=-1}^{l} \sqrt{\frac{4\pi}{2l+1}} D_l(r) L_{l,m} Y_{l,m}(n)$$

Ambient Skin (Diffuse only)

Left is using normal SH lighting convolved with cosine kernel

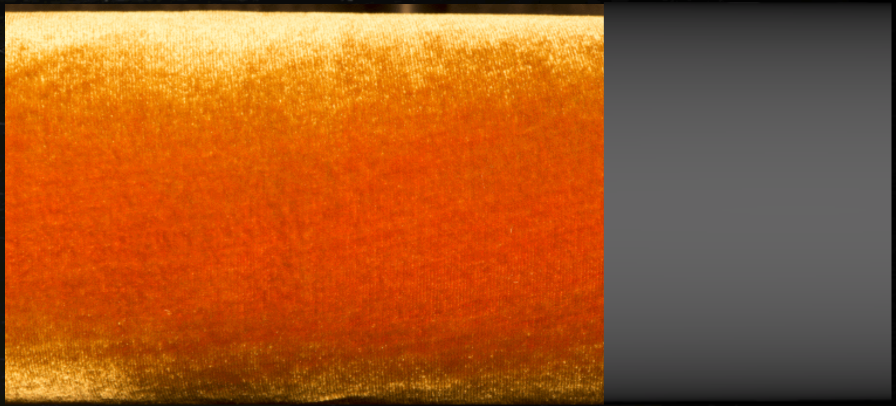
Right is using SH lighting convolved with the scattering kernel

Cloth Shading

Cloth Shading

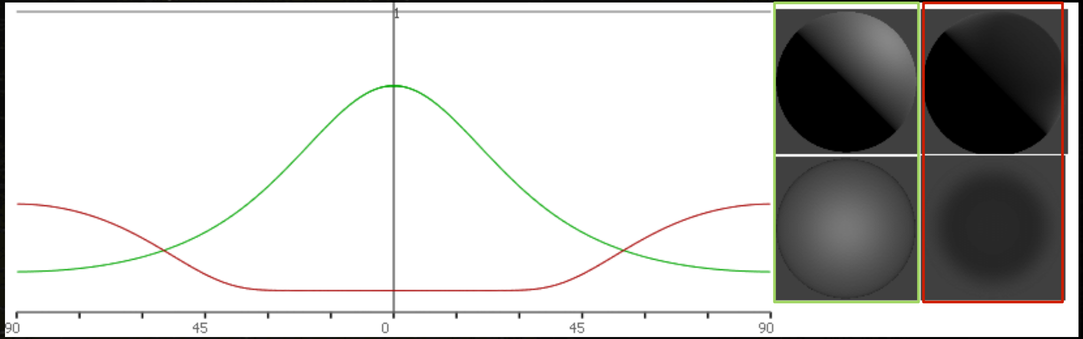
Observations from photo reference:

- Soft specular lobe with large smooth falloffs
- Fuzz on the rim from asperity scattering
- Low specular contribution at front facing angles
- Some fabrics have two toned specular colors

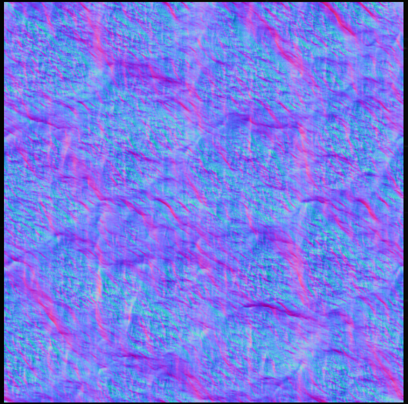


Cloth Shading

- Inverted Gaussian for asperity scattering
- Translation from origin to give more specular at front facing angles
- No geometry term



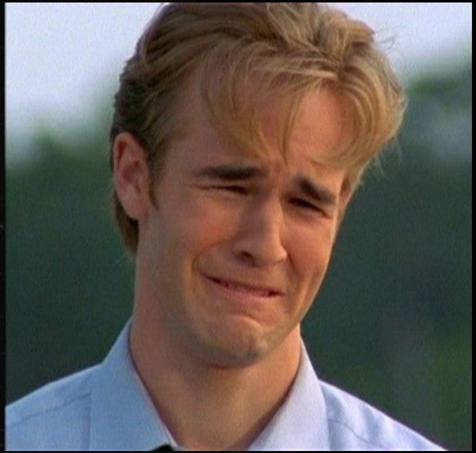
Specular Aliasing



$+$

$$f(\mathbf{l},\mathbf{v}) = \frac{F(\mathbf{v},\mathbf{h})\,G(\mathbf{l},\mathbf{v},\mathbf{h})\,D(\mathbf{h})}{4\,(\underline{\mathbf{n}\cdot\mathbf{l}})\,(\underline{\mathbf{n}\cdot\mathbf{v}})}$$

$=$



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Specular Aliasing

- Modify roughness maps to reduce aliasing
- Using technique based on "Frequency Domain Normal Map Filtering" by Han et al.

$$f^{\text{eff}}(\mathbf{l}, \mathbf{v}; \gamma) = \int_{\Omega} f(\mathbf{l}, \mathbf{v}) \gamma(\mathbf{n}) d\mathbf{n}$$

$$f^{\text{eff}}_{lm} = \sqrt{\frac{4\pi}{2l+1}} f_l \gamma_{lm}$$

Specular Aliasing

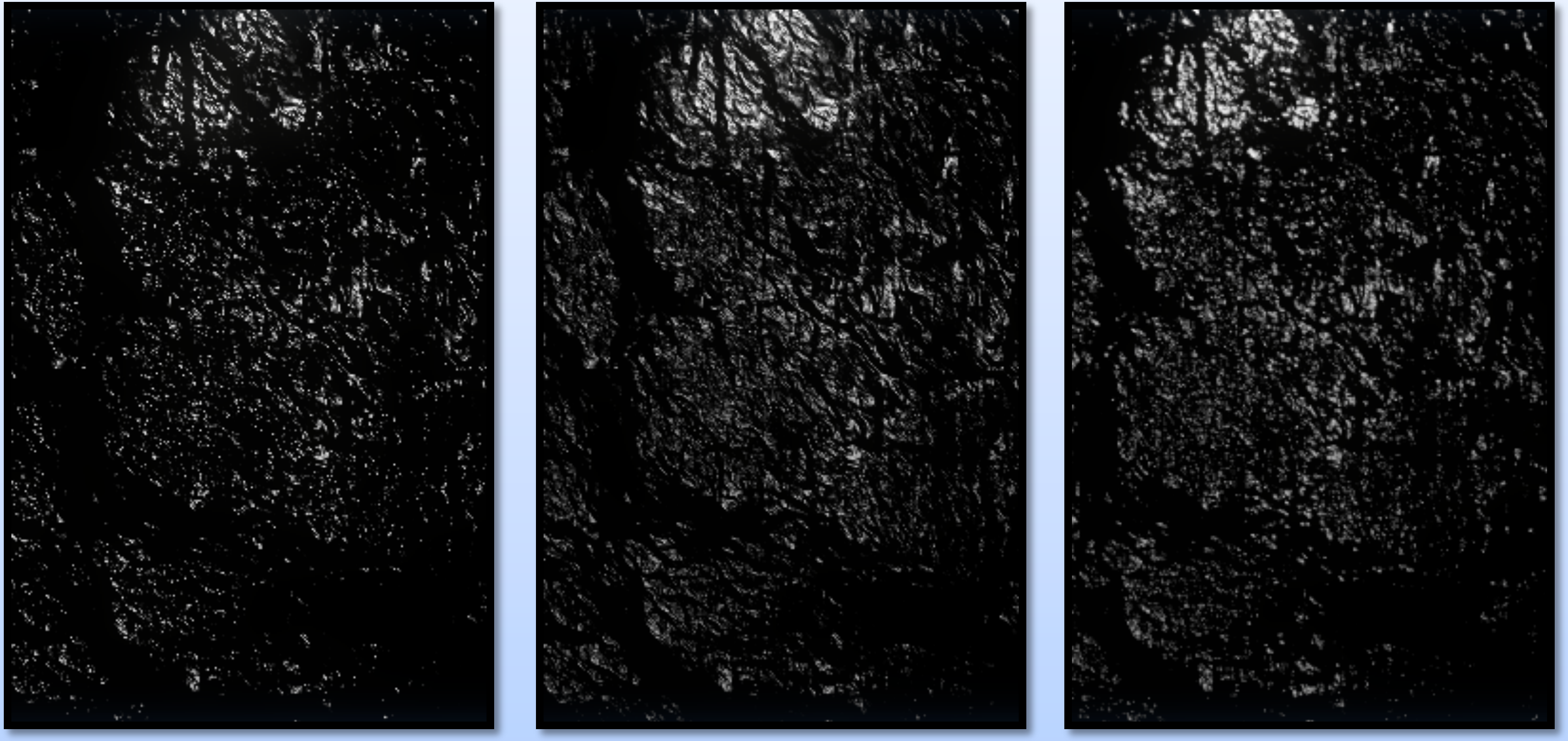
- Represent NDF as spherical Gaussian (vMF distribution)
- Approximate BRDF in SH as a Gaussian
- Convolution of two Gaussians is a new Gaussian
- Use relationship to compute new roughness

BRDF NDF

$$\Lambda_l f_l^{\text{eff}} = \underbrace{e^{(\alpha l)^2}}_{\text{BRDF}} \underbrace{e^{-\frac{l^2}{2\kappa}}}_{\text{NDF}} = e^{(\alpha' l)^2}$$

New Roughness

$$\alpha' = \sqrt{\alpha^2 + (2\kappa)^{-1}}$$

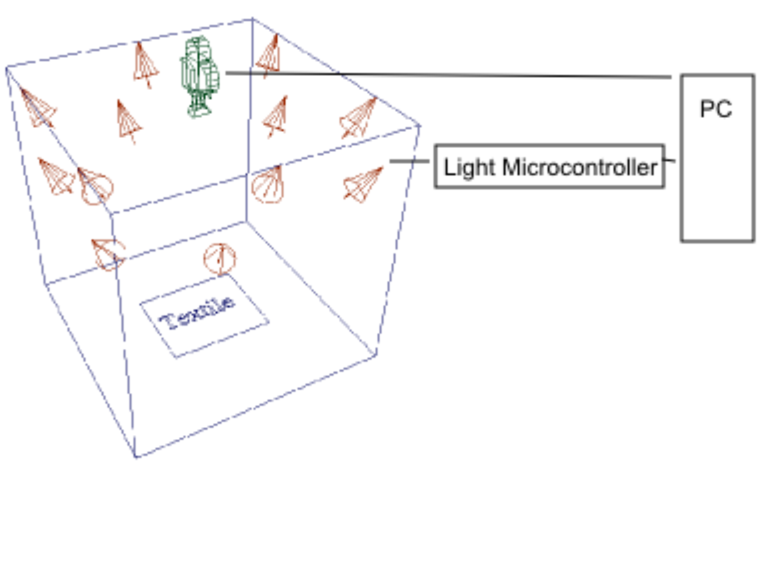


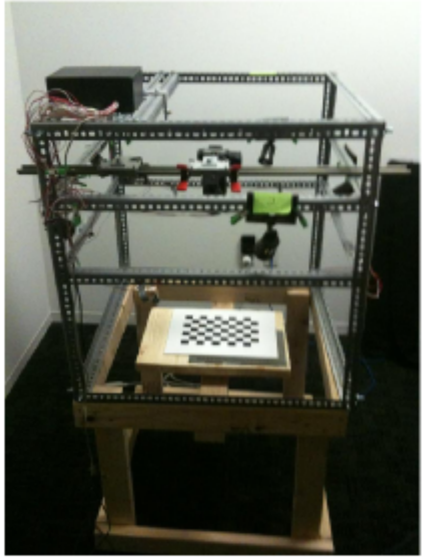
No AA Ours Ground Truth

3D Material Scanning

- Play 3d Material Scanning Video

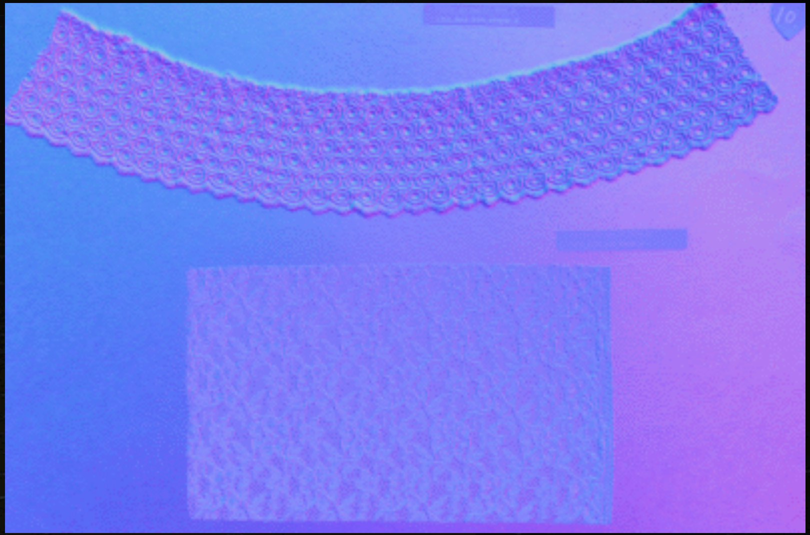
Scanning





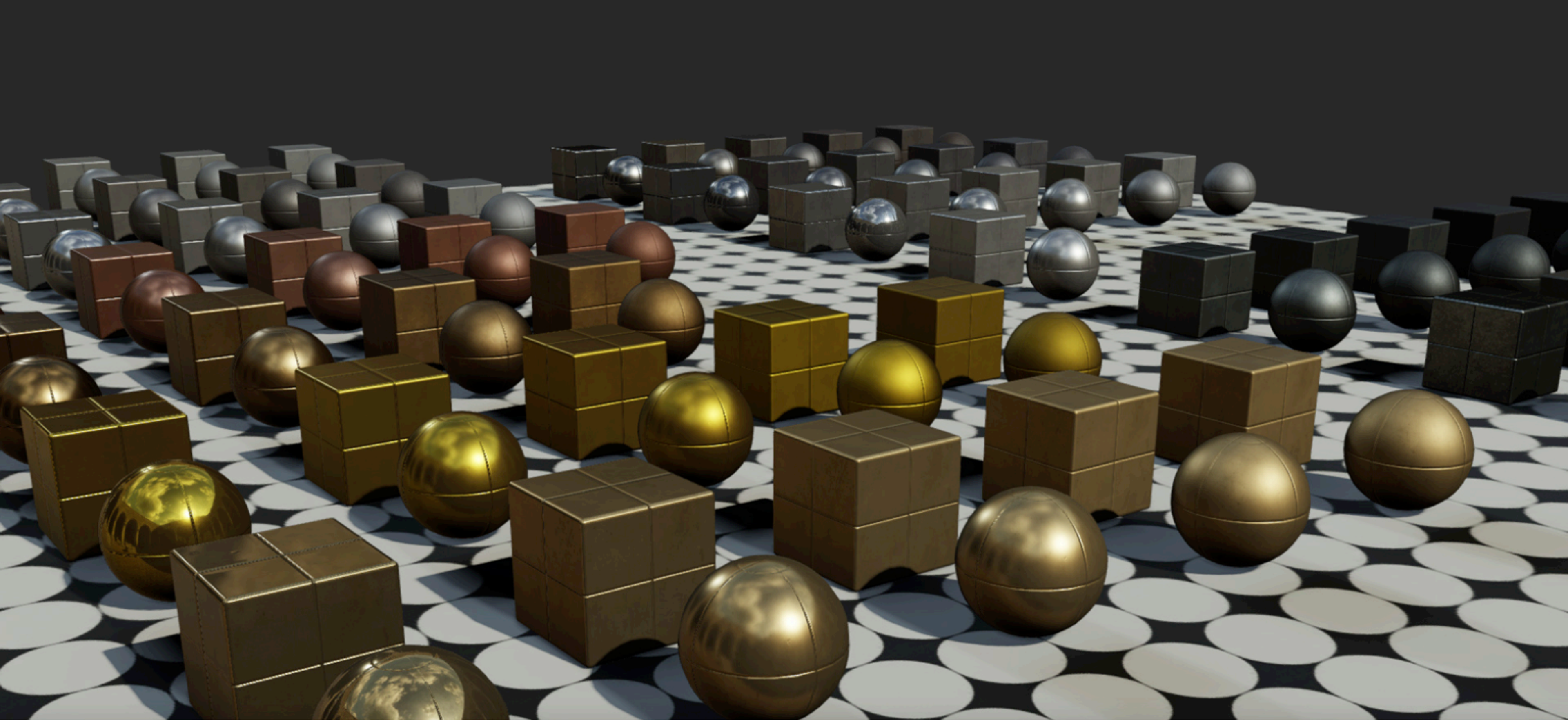
Scanning Calibration

- Errors in calibration caused low frequency errors in solved normal map
- Better estimation of parameters = better normals
  - Light direction
  - Light intensity
  - Geometric distortion
  - Radial distortion
  - Chromatic aberration



Material Authoring Pipeline

- 3 pillars of the material pipeline
  - Inheritance-based data format
  - Compositing
  - Run-time layering

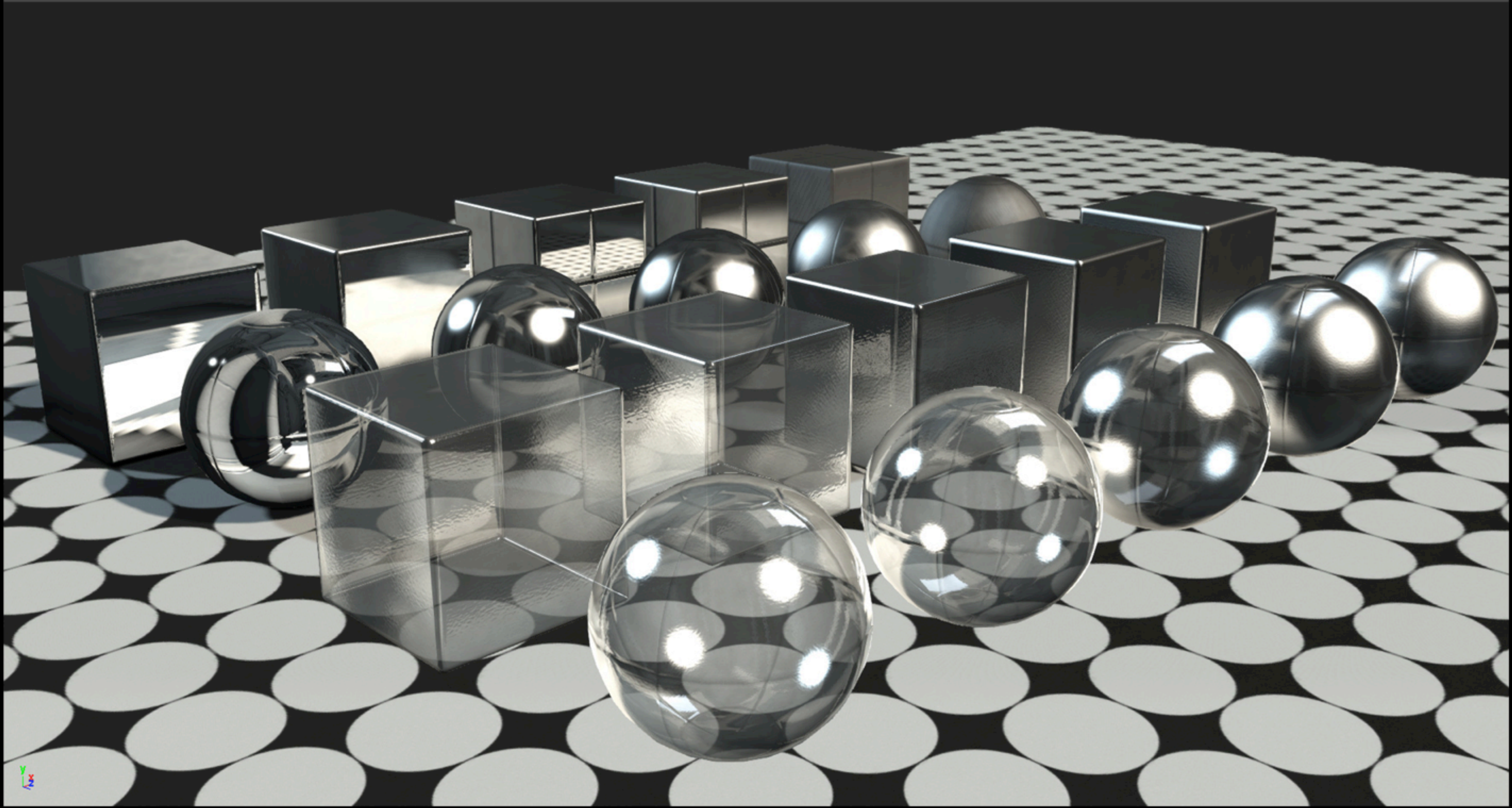


Material Templates

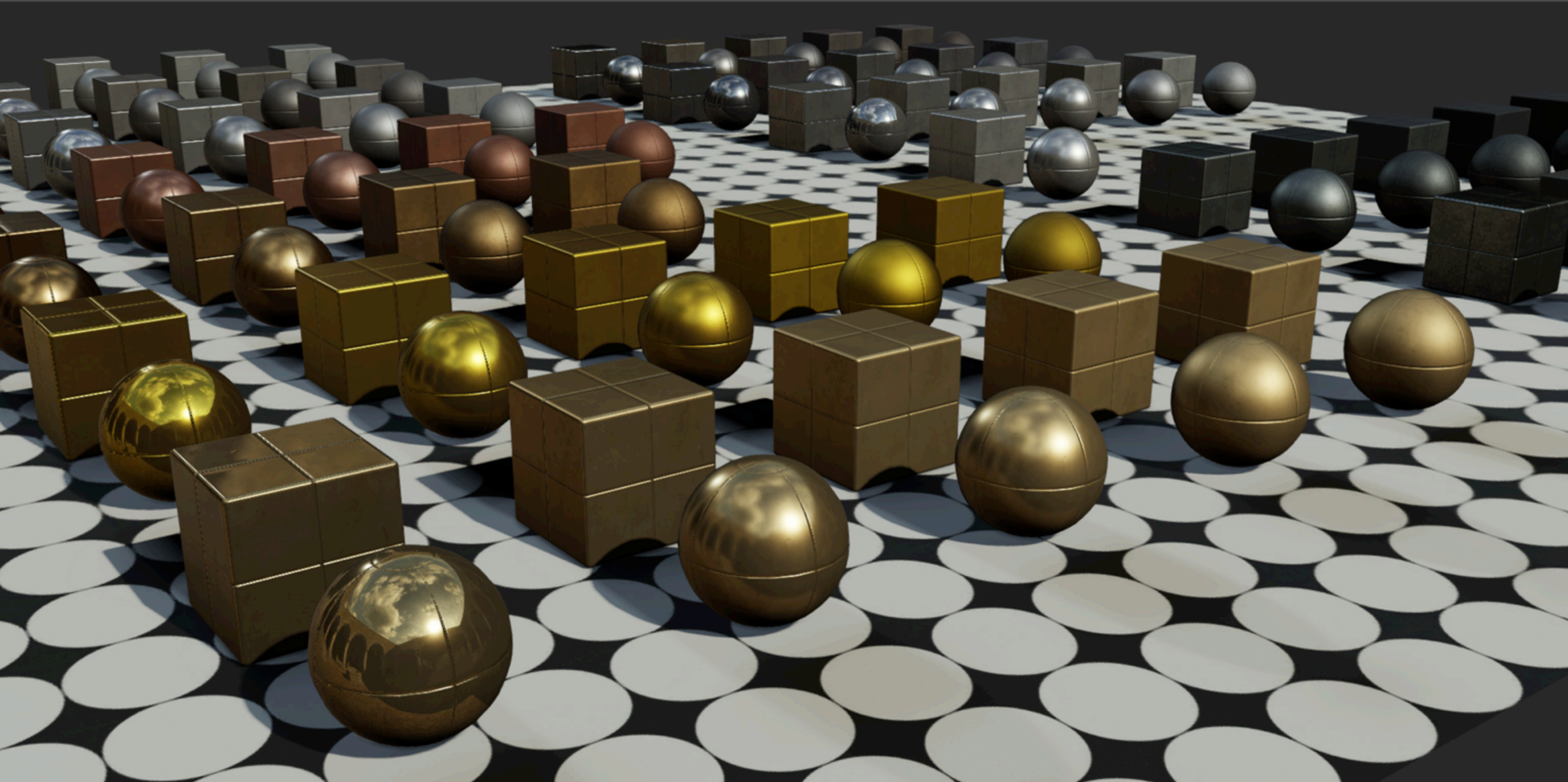
Inheritance-based Materials

- Common parameters shared in base material
- Derived material only stores changes from base
- Quicker asset creation
- Global changes can be made in a single asset

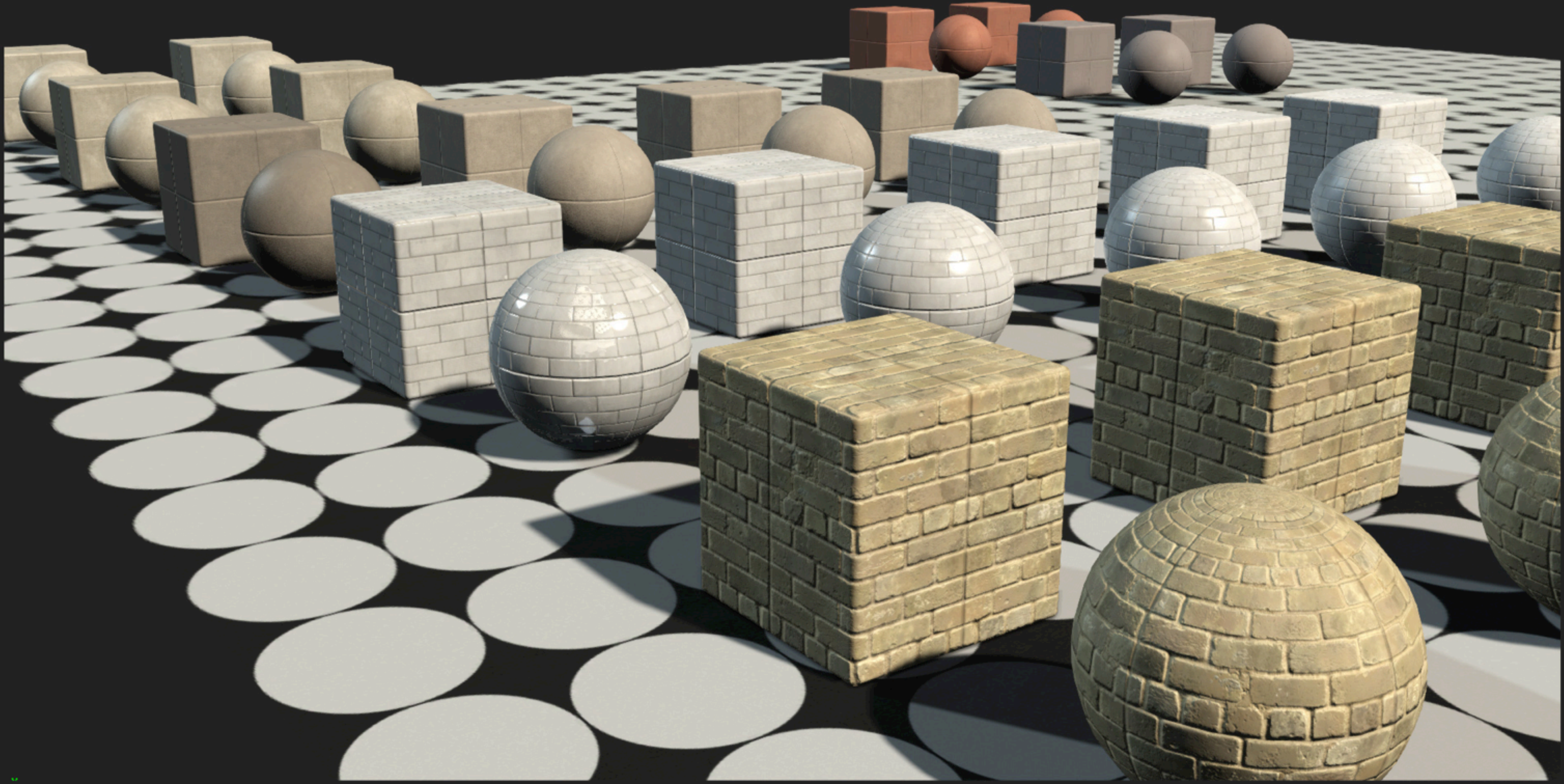
Global Material Templates: Sample Glass Subset



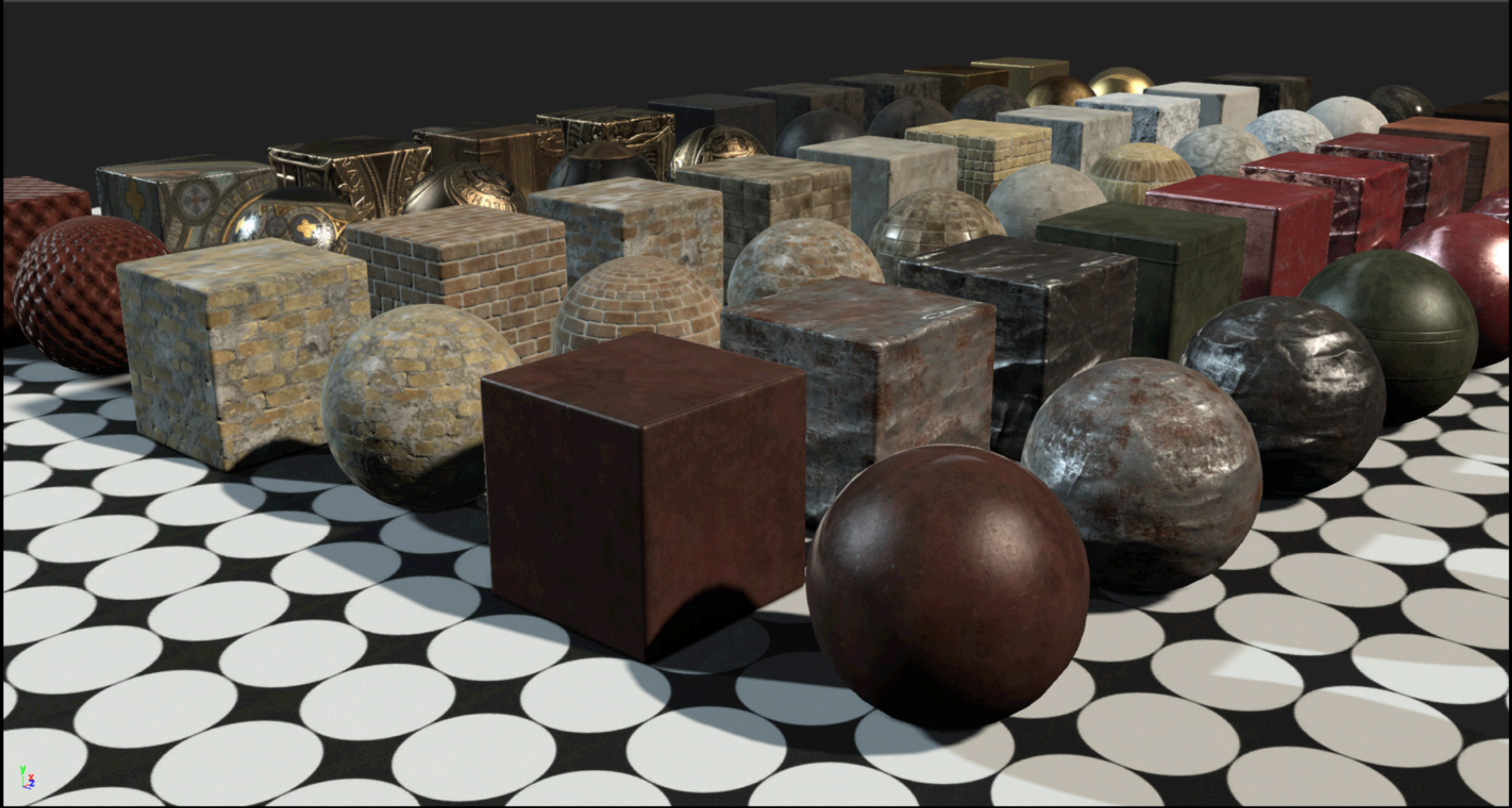
Global Material Templates: Sample Metal Subset



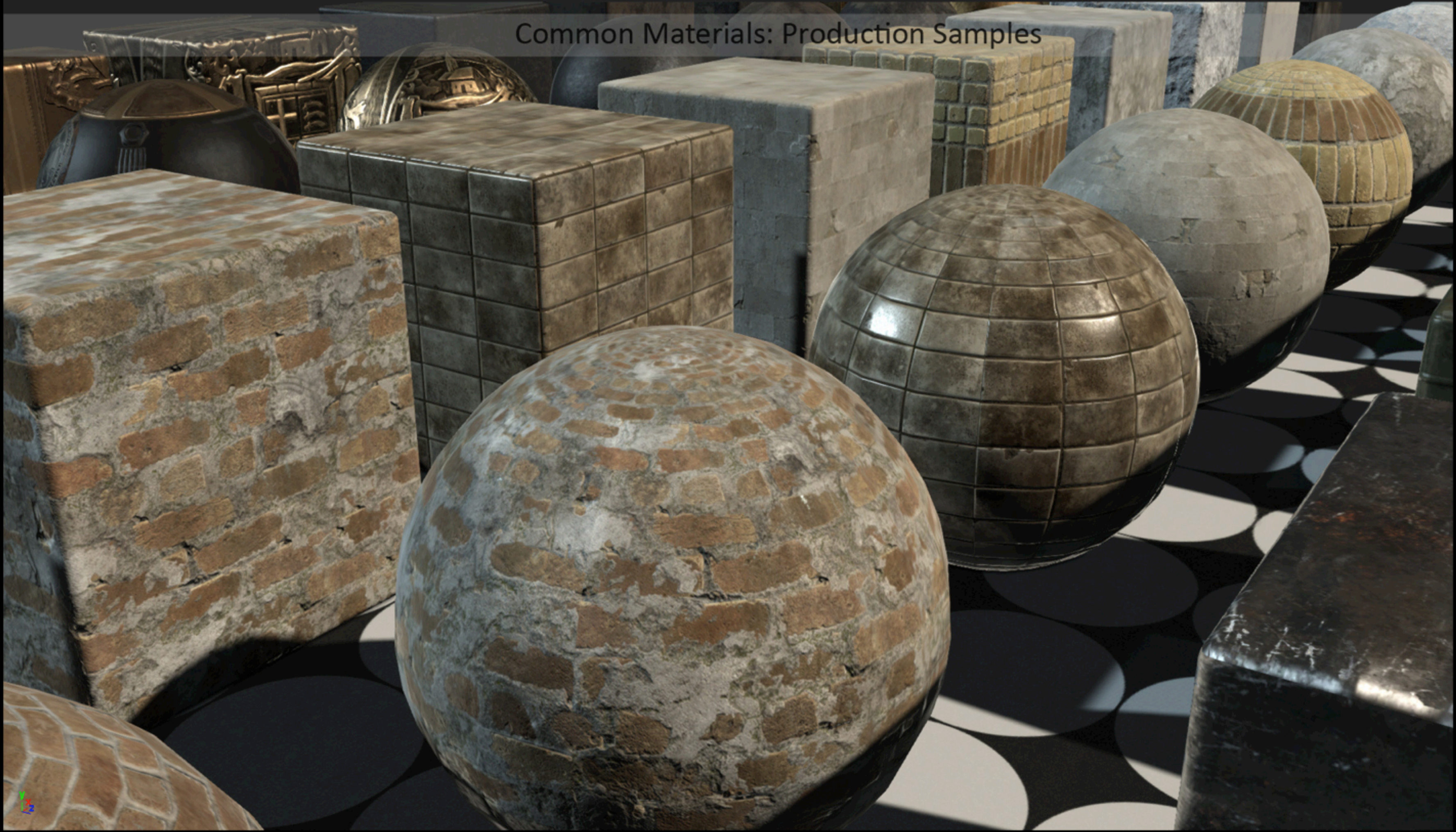
Global Material Templates: Sample Masonry Subset



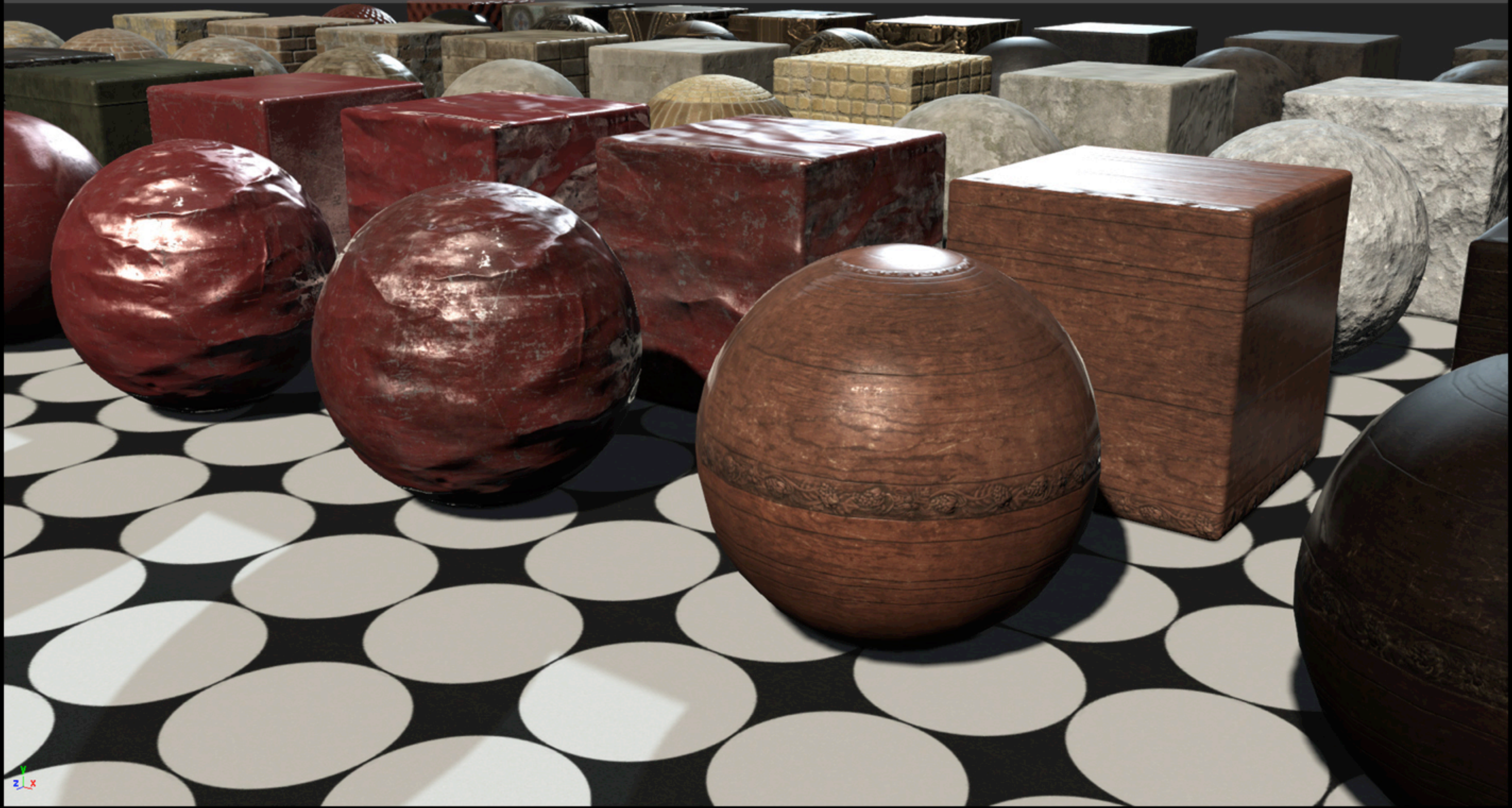
Common Materials: Production Samples



Common Materials: Production Samples



Common Materials: Production Samples



Common Materials: Production Samples

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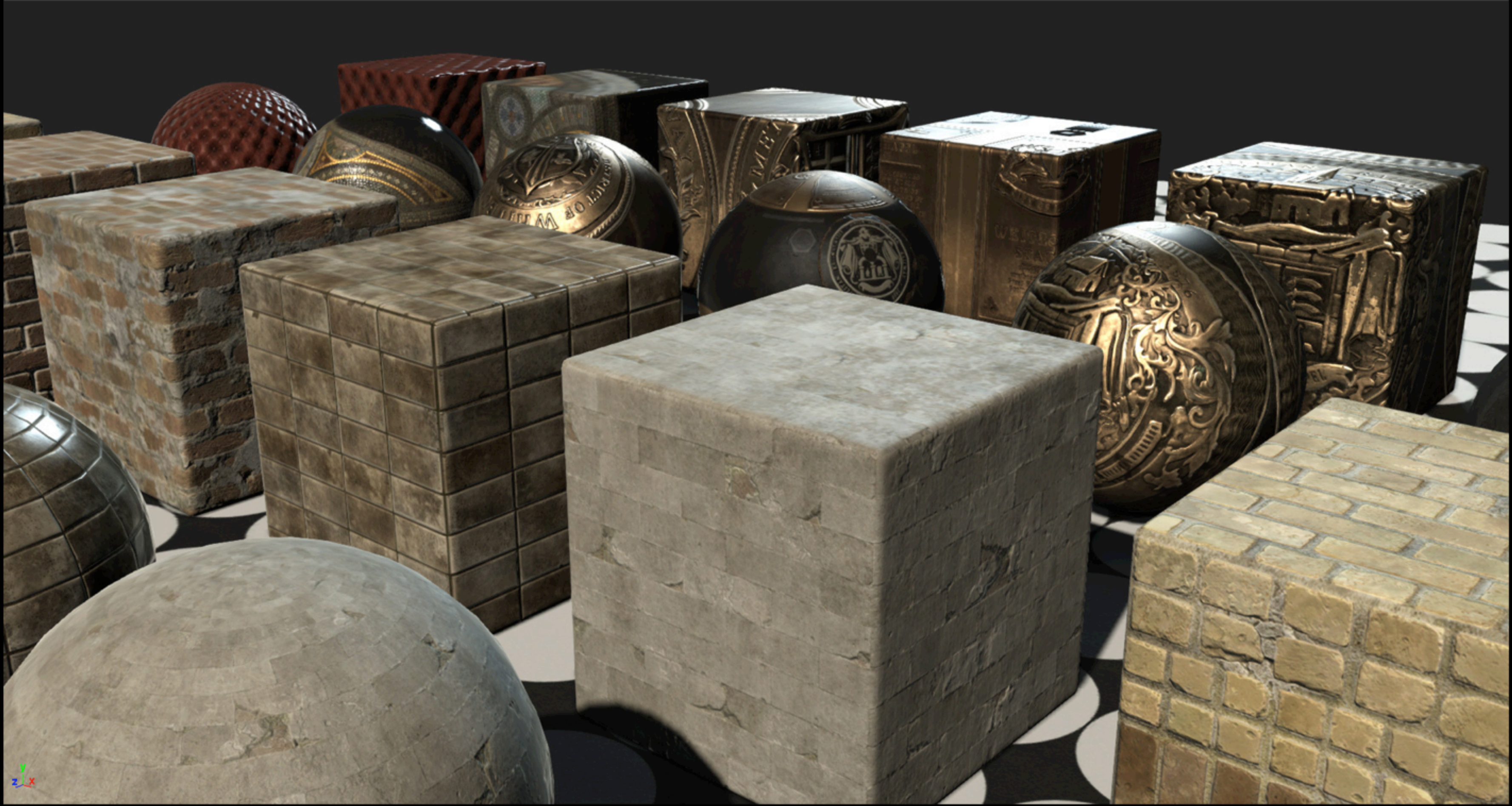
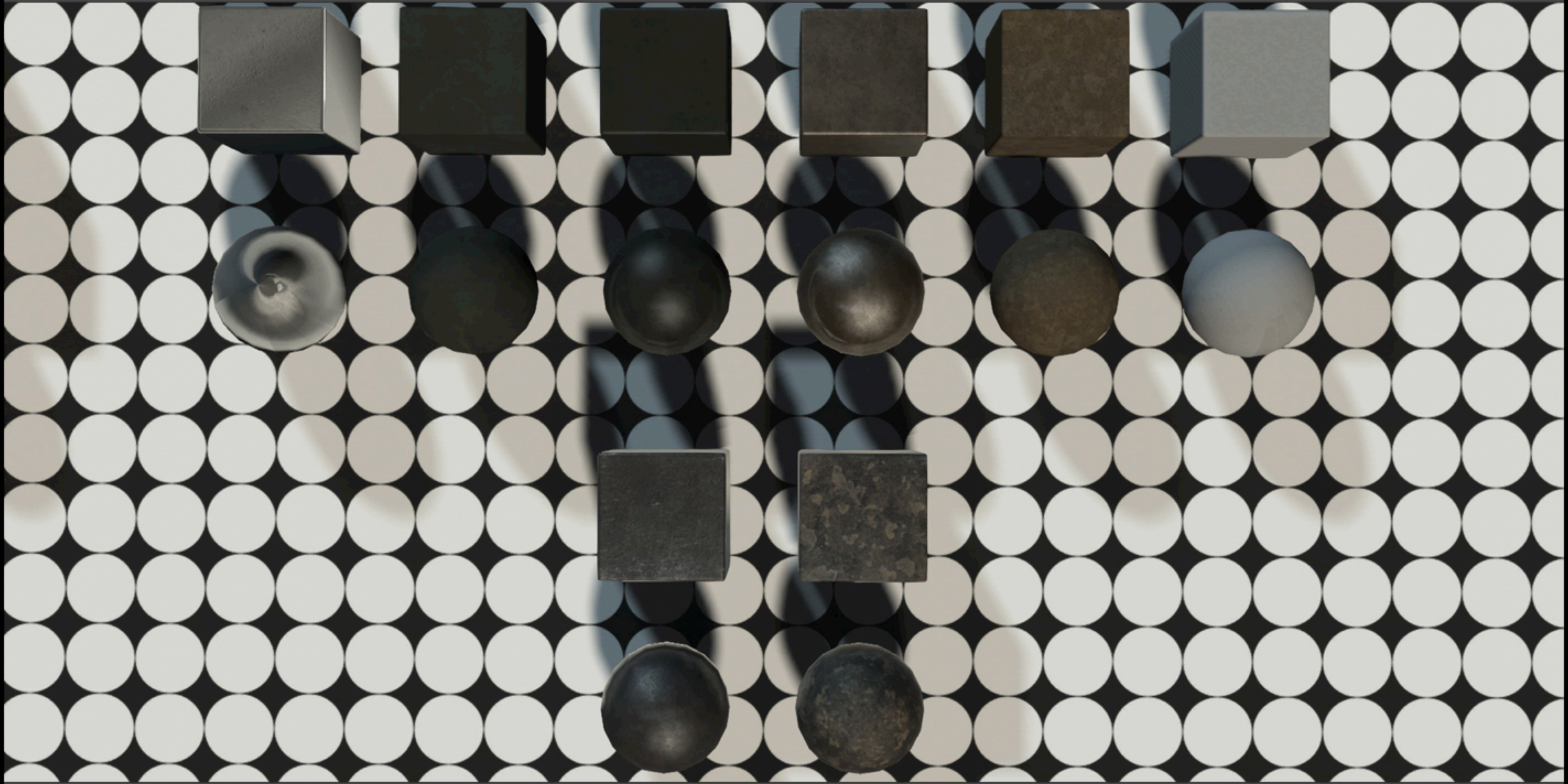
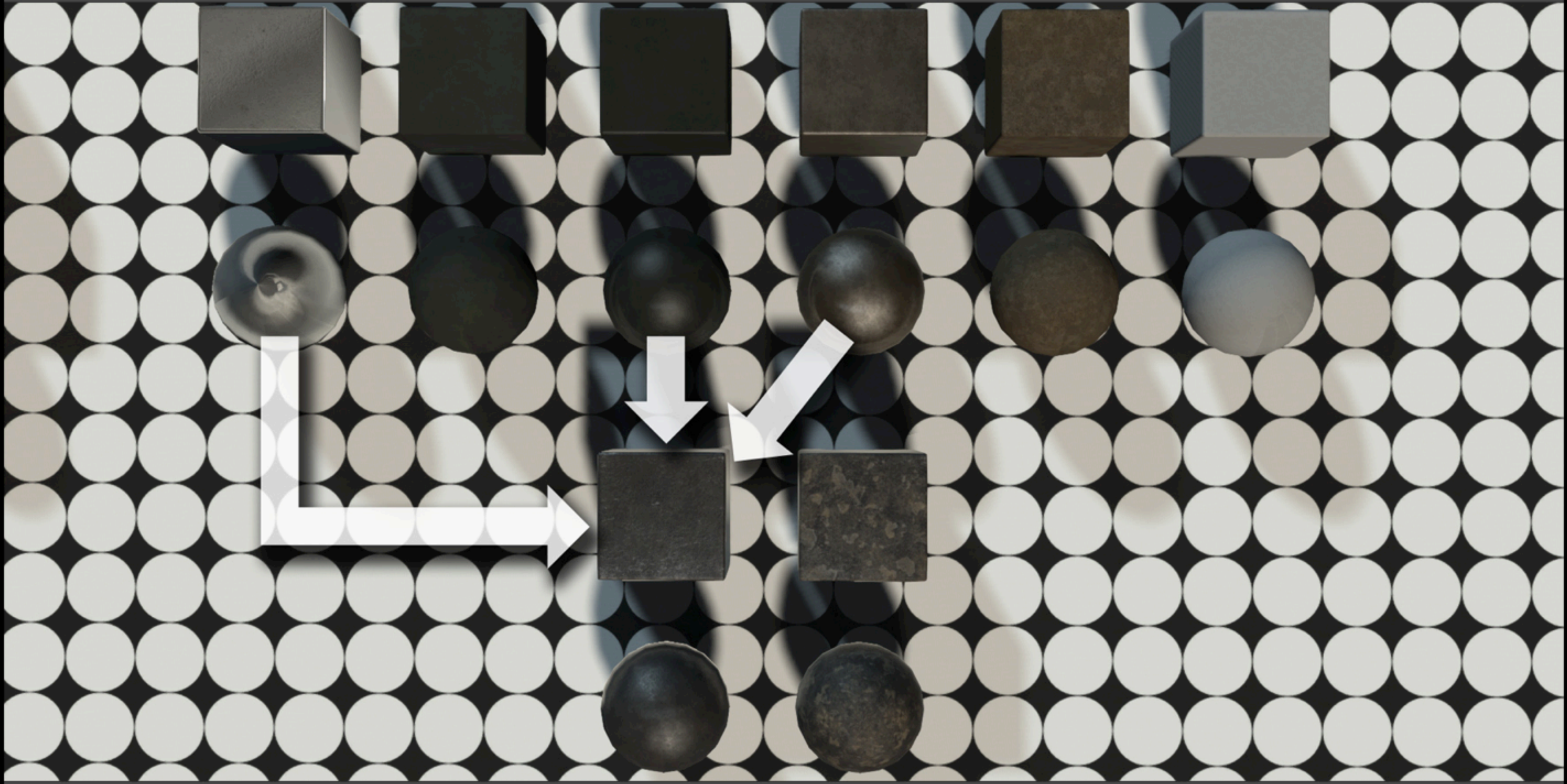


Global Material Templates



Inherited Common Materials

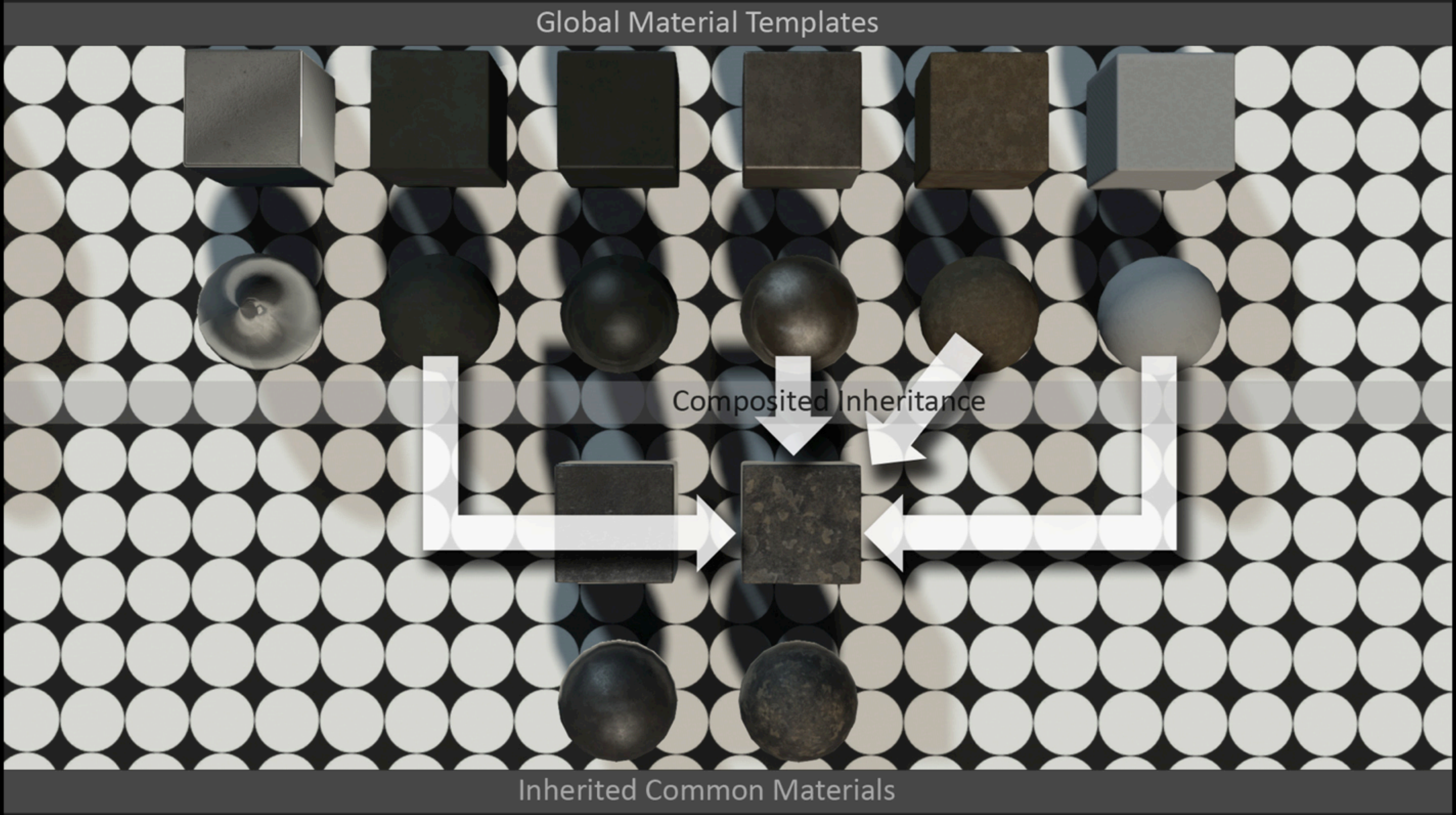
Global Material Templates



Inherited Common Materials

Global Material Templates

Inherited Common Materials


Global Material Templates
Composited Inheritance
Inherited Common Materials

Material Compositing

Material Compositing

- Mostly offline process
- Generates parameter maps from materials and blending maps
- Support compositing subset of BRDFs
  - Cloth, GGX, and Anisotropic
  - Compositing cloth requires applying 2 BRDFs

Material Compositing

Map	R Channel	G Channel	B Channel	A Channel	Format
1	Normals X	Normals Y	N/A	N/A	BC5
2	Diffuse R	Diffuse G	Diffuse B	Alpha (Optional)	BC1 or BC3
3	Specular R	Specular G	Specular B	Specular Intensity	BC3
4	Roughness	AO	BRDF Blend	Anisotropy	BC3

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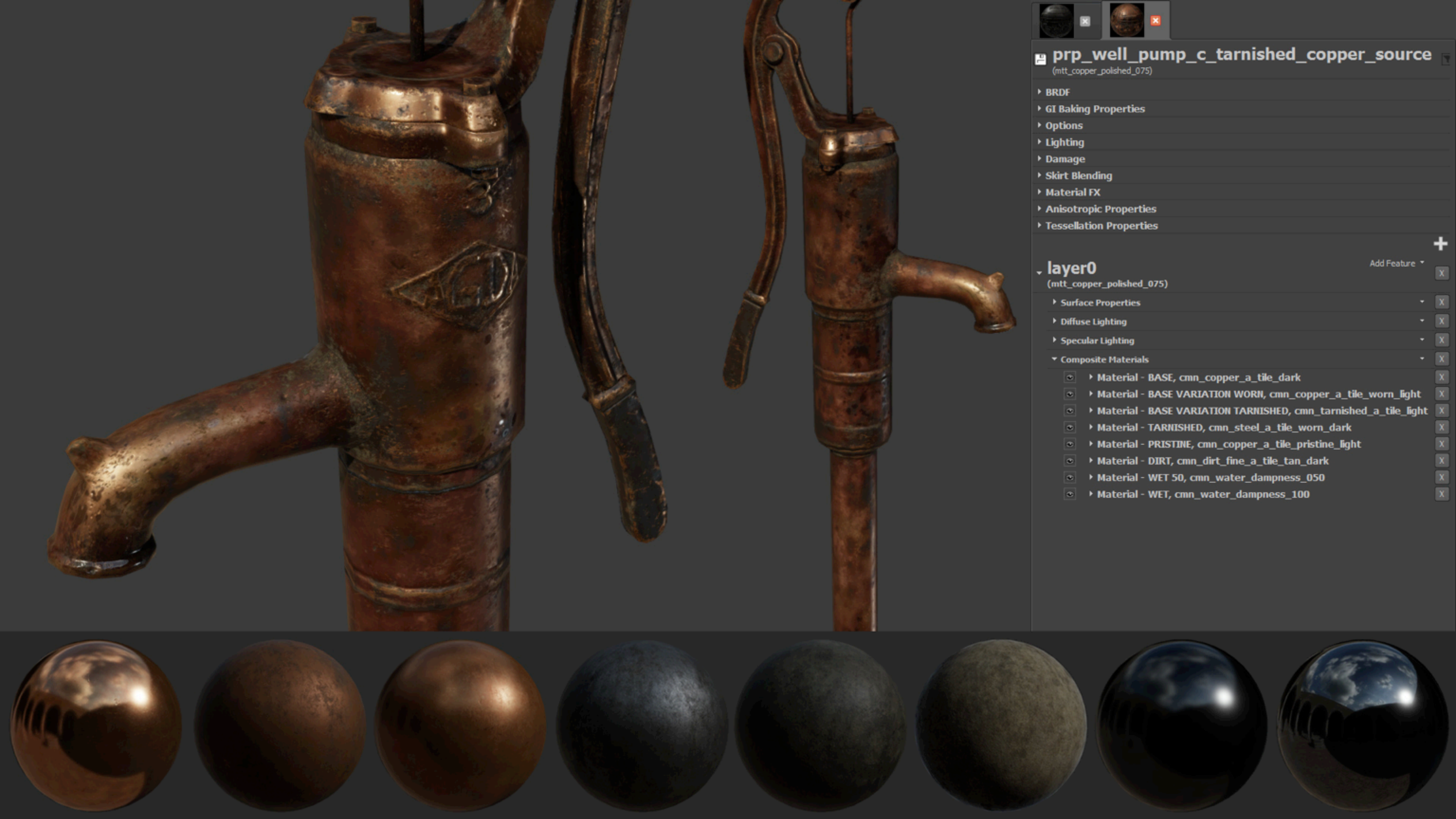
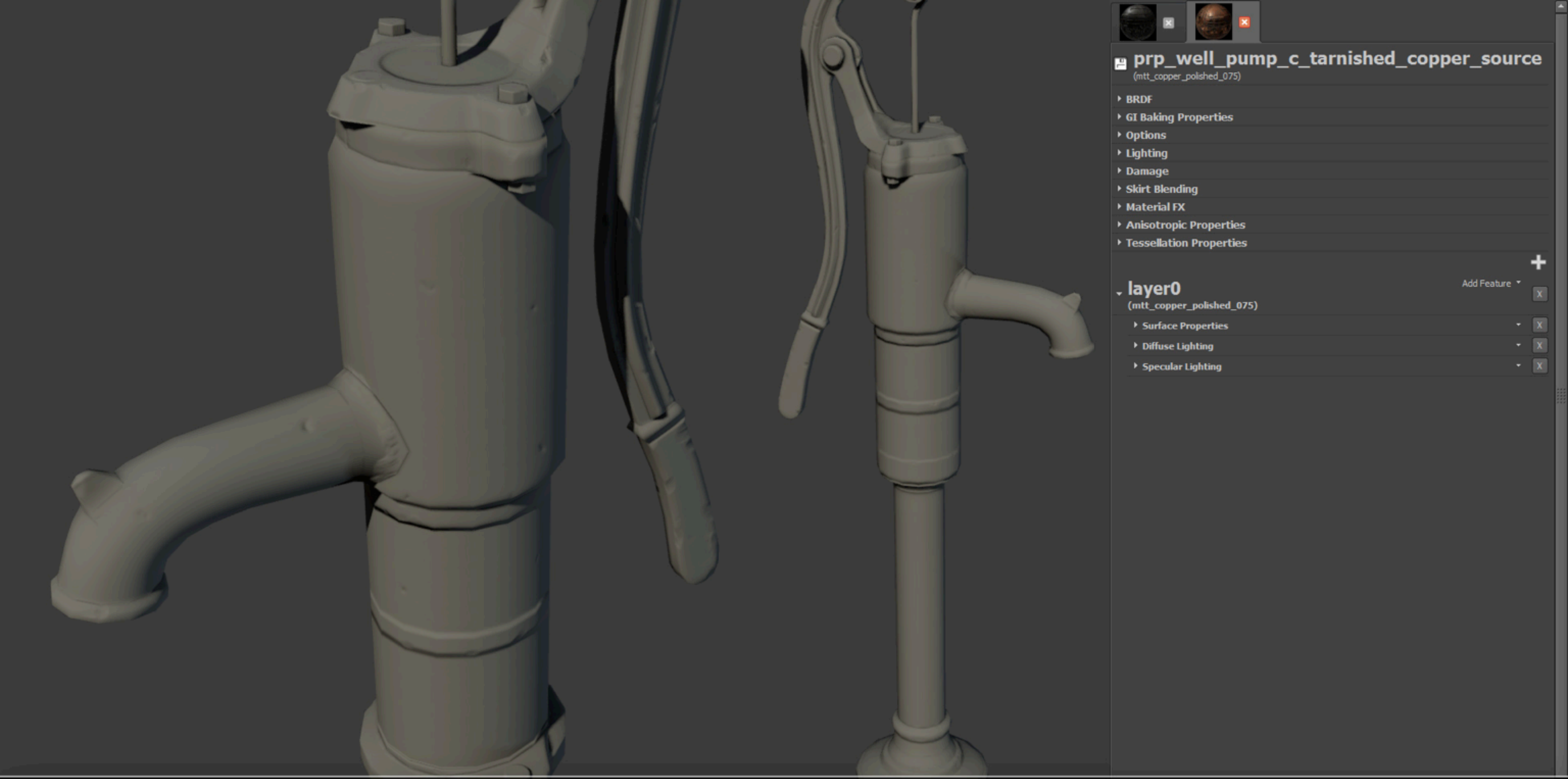
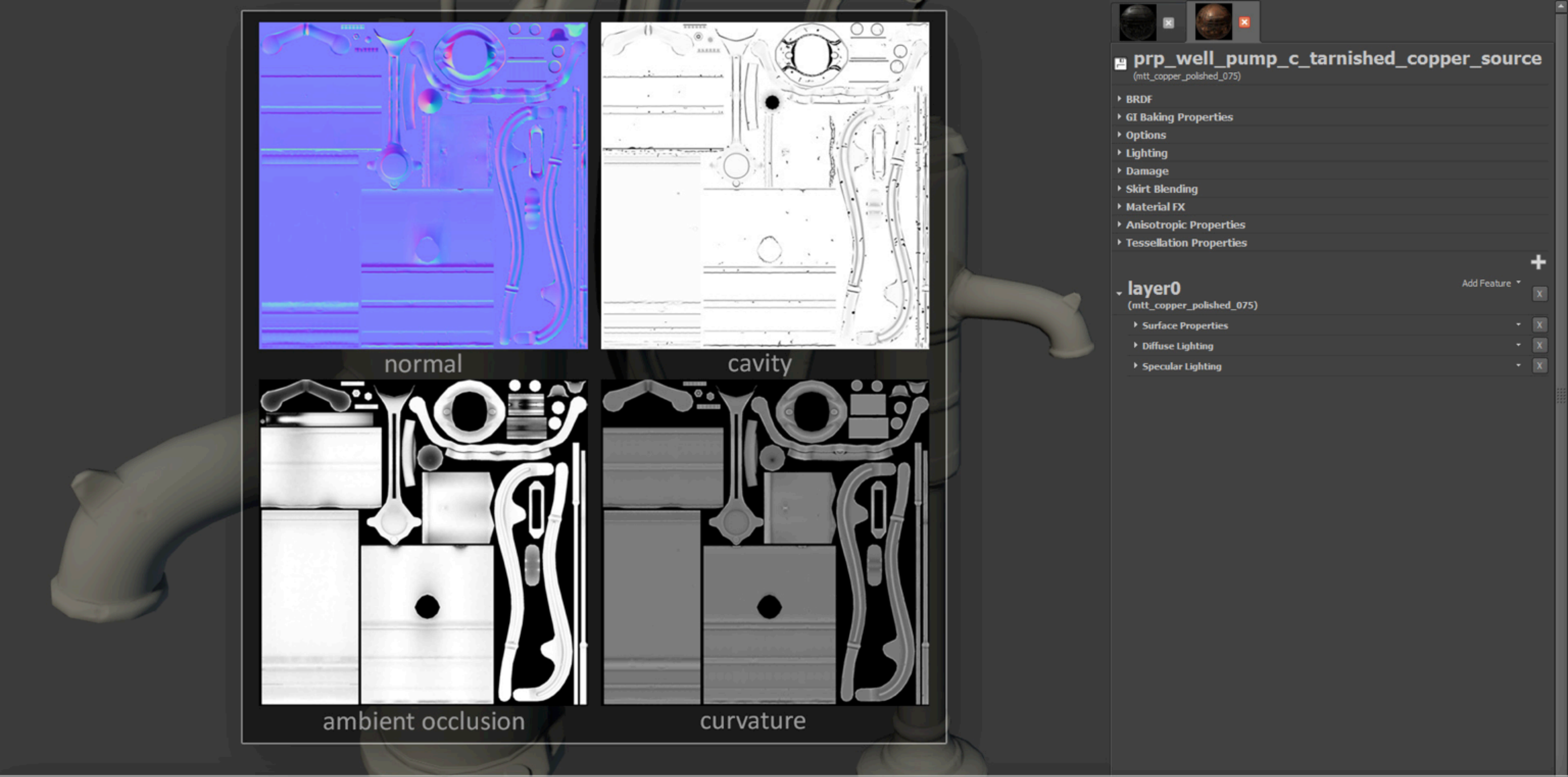
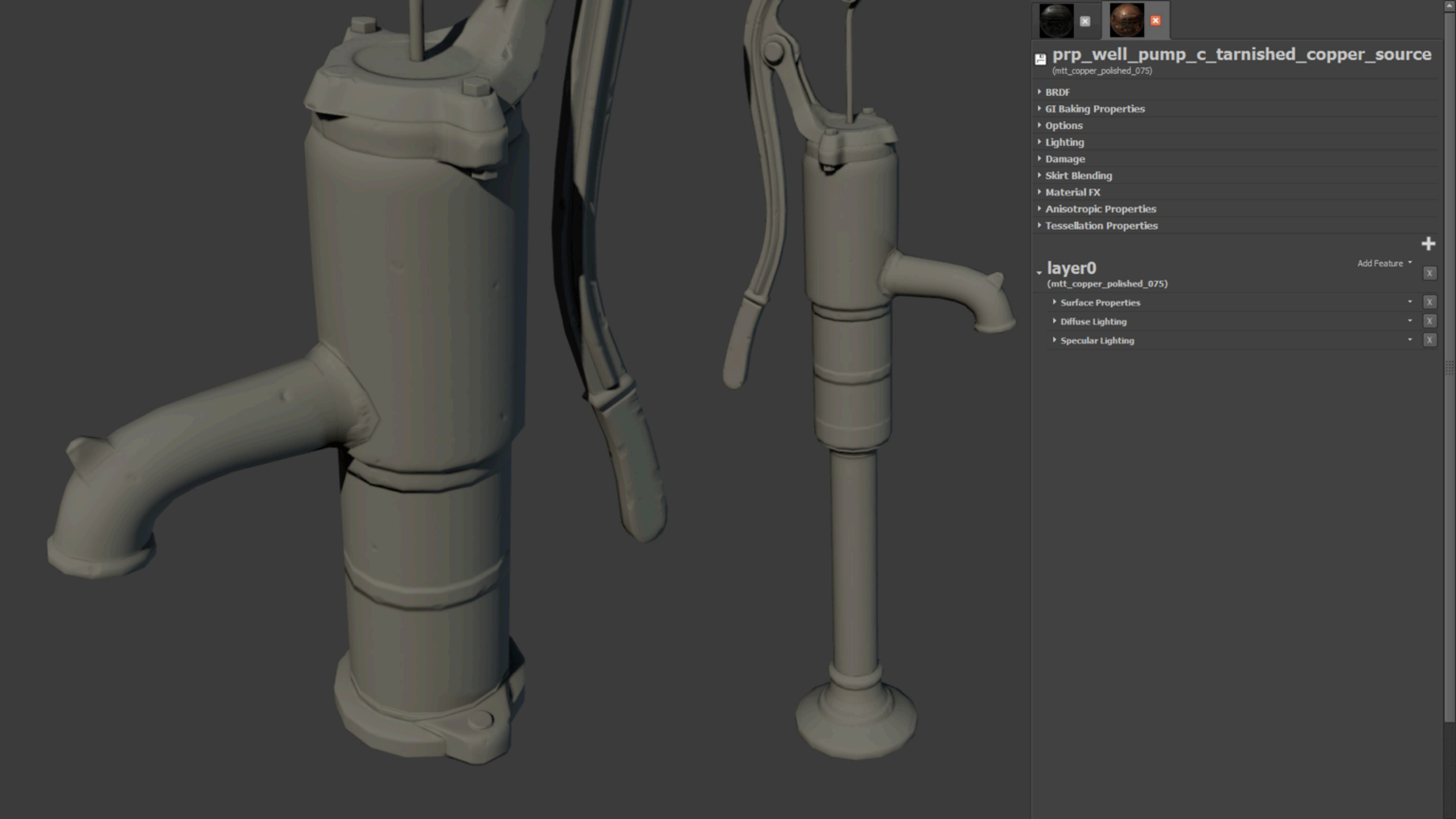

prp_well_pump_c_tarnished_copper_source
(mtt_copper_polished_075)
BRDF
GI Baking Properties
Options
Lighting
Damage
Skirt Blending
Material FX
Anisotropic Properties
Tessellation Properties
Add Feature
layer0
(mtt_copper_polished_075)
Surface Properties
Diffuse Lighting
Specular Lighting
Composite Materials
Material - BASE, cmn_copper_a_tile_dark
Material - BASE VARIATION WORN, cmn_copper_a_tile_worn_light
Material - BASE VARIATION TARNISHED, cmn_tarnished_a_tile_light
Material - TARNISHED, cmn_steel_a_tile_worn_dark
Material - PRISTINE, cmn_copper_a_tile_pristine_light
Material - DIRT, cmn_dirt_fine_a_tile_tan_dark
Material - WET 50, cmn_water_dampness_050
Material - WET, cmn_water_dampness_100



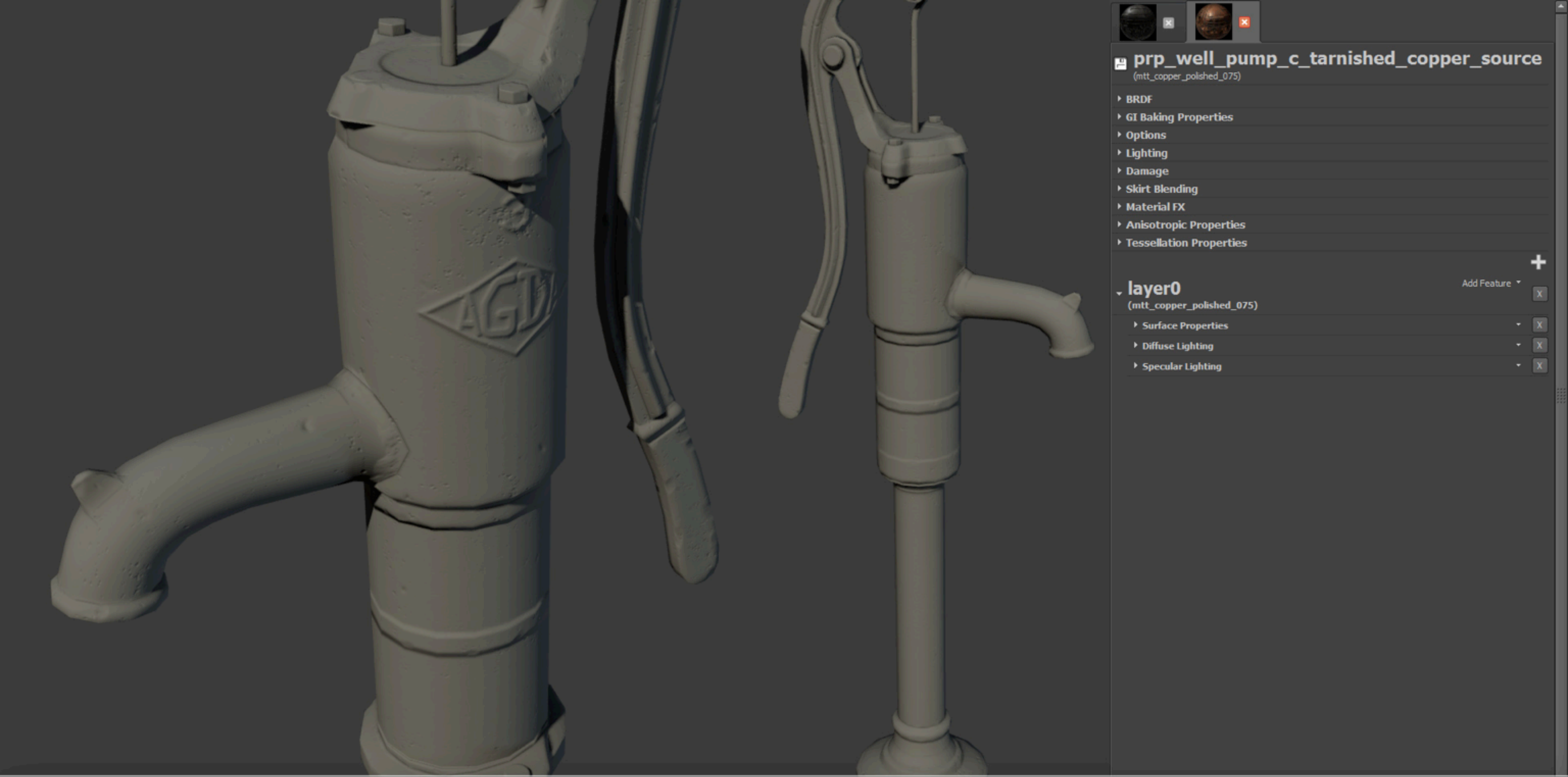
base game asset as received back from outsource artist



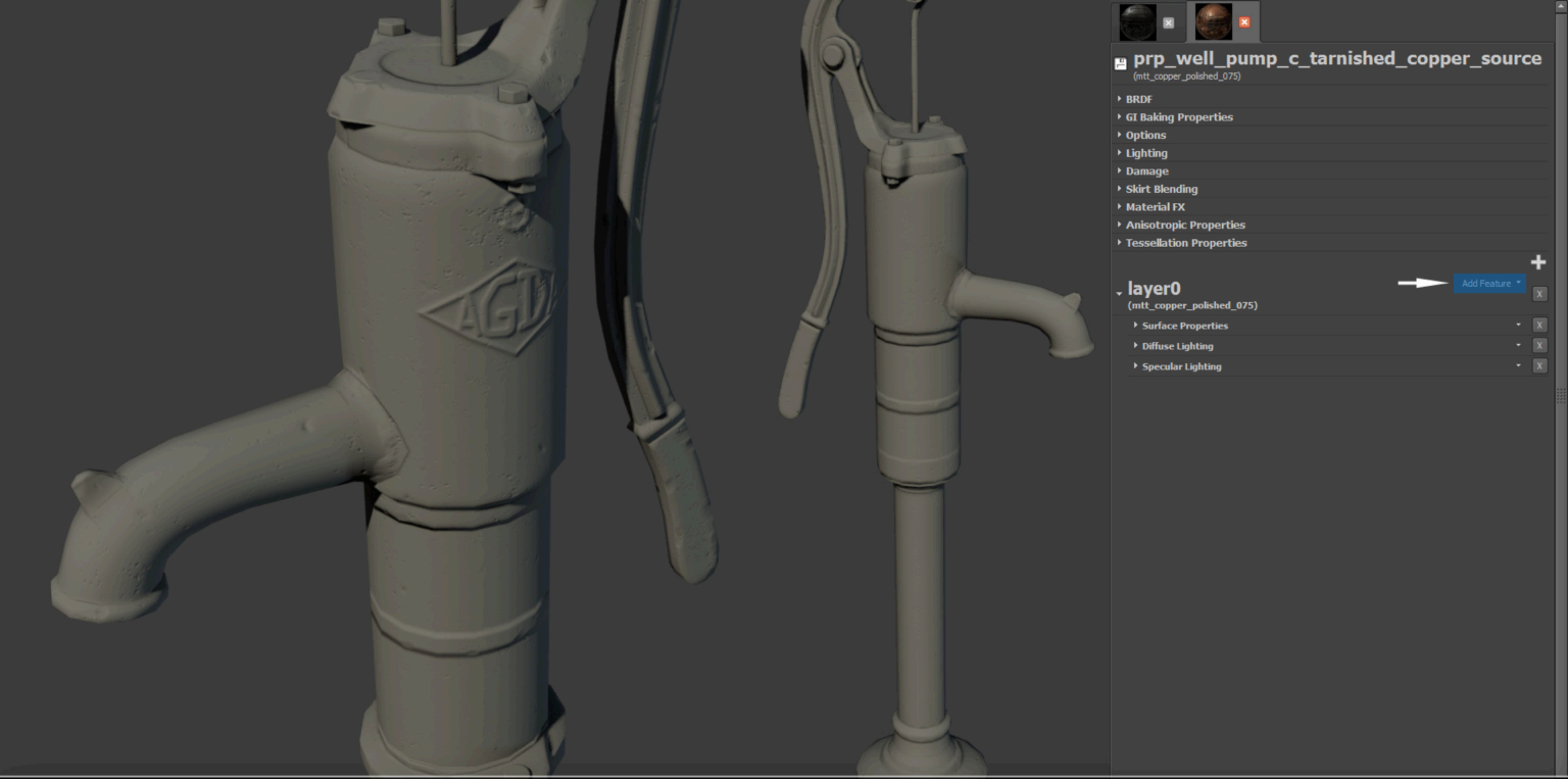
Sample support maps baked from highres asset



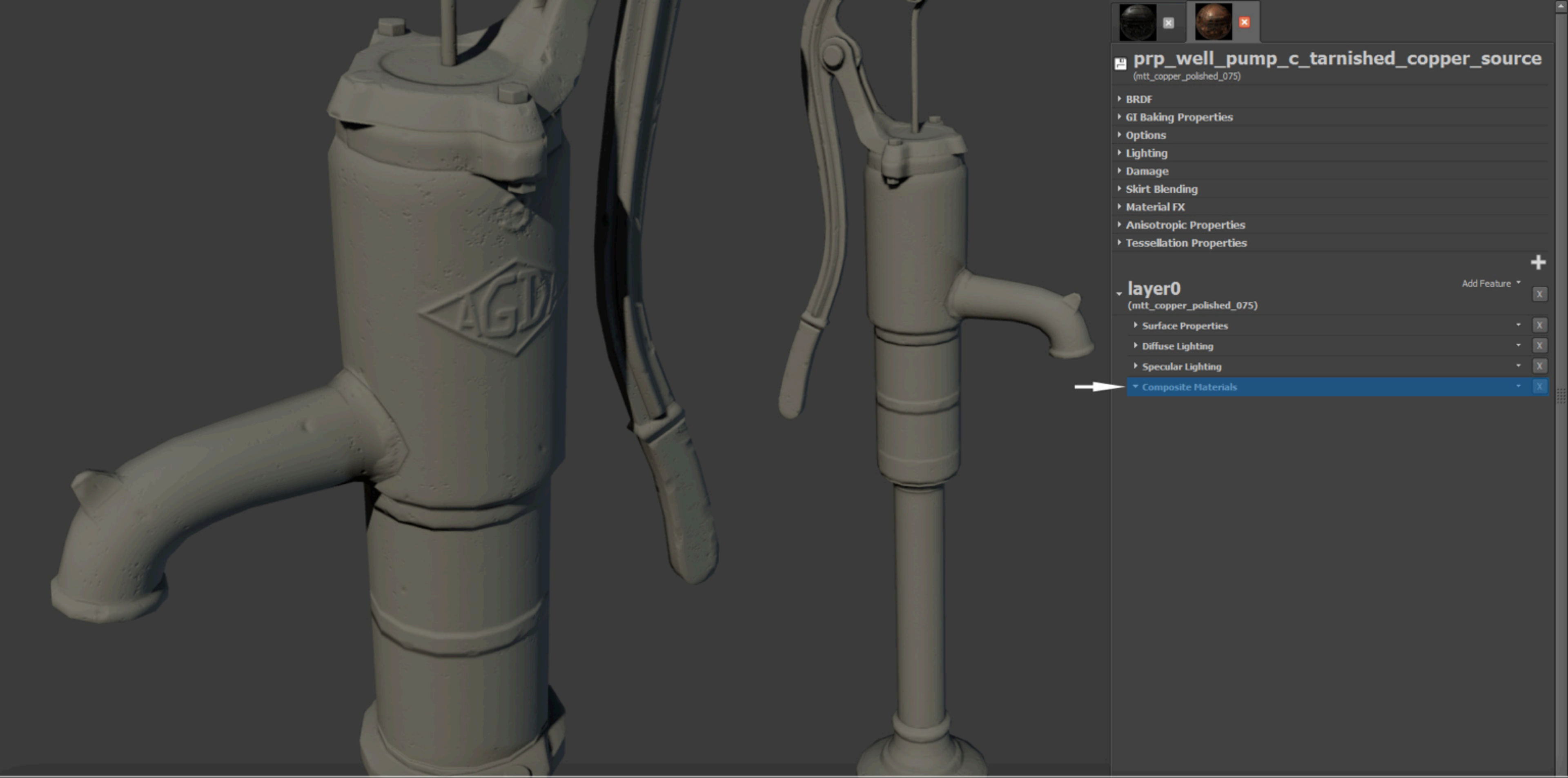
prp_well_pump_c_tarnished_copper_source
(mtt_copper_polished_075)
BRDF
GI Baking Properties
Options
Lighting
Damage
Skirt Blending
Material FX
Anisotropic Properties
Tessellation Properties
Add Feature
layer0
(mtt_copper_polished_075)
Surface Properties
Diffuse Lighting
Specular Lighting



texture artist adds markings and additional micro detail to the normal using Mari



In the material editor the texture artist adds our compositing feature



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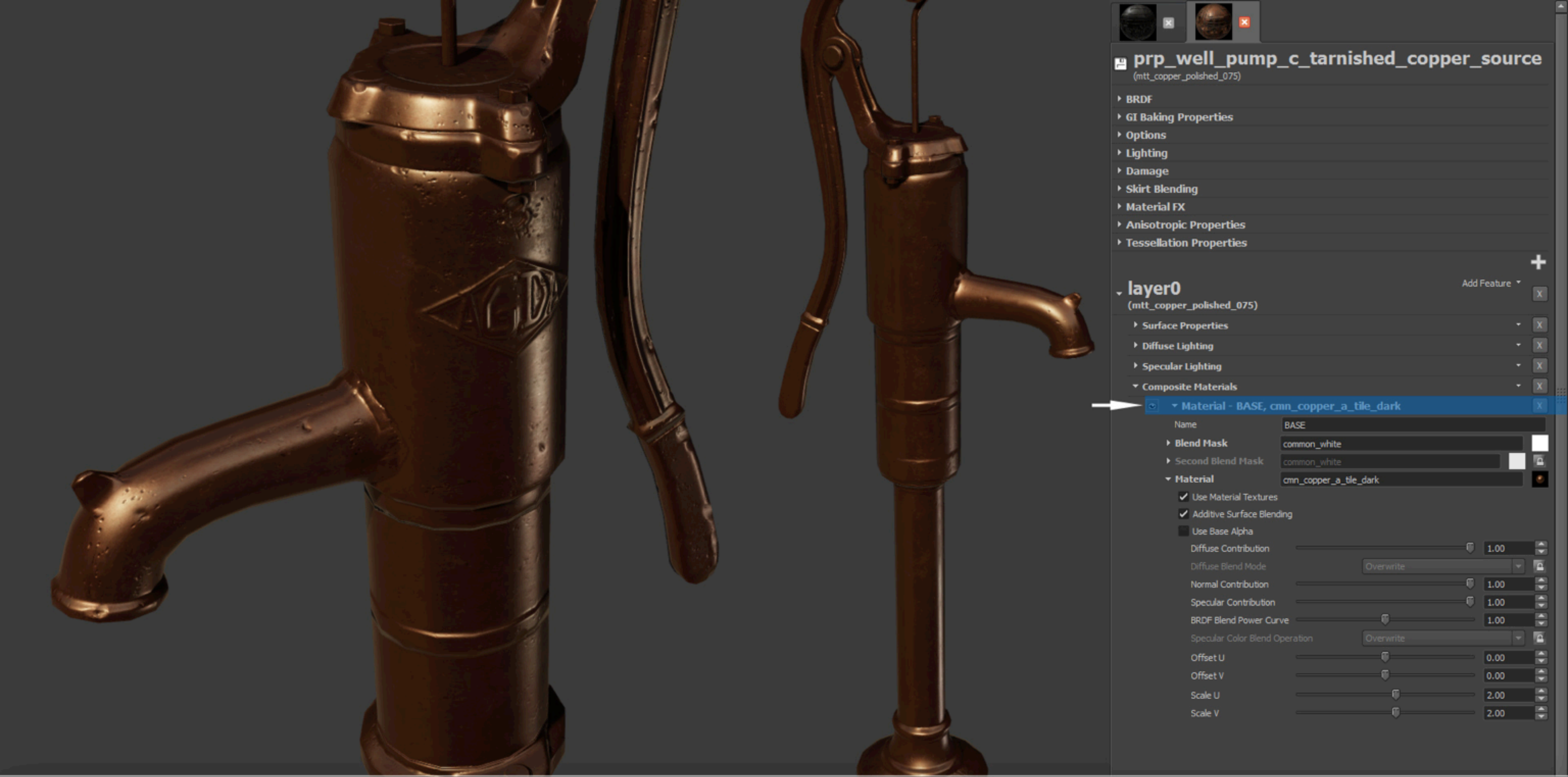
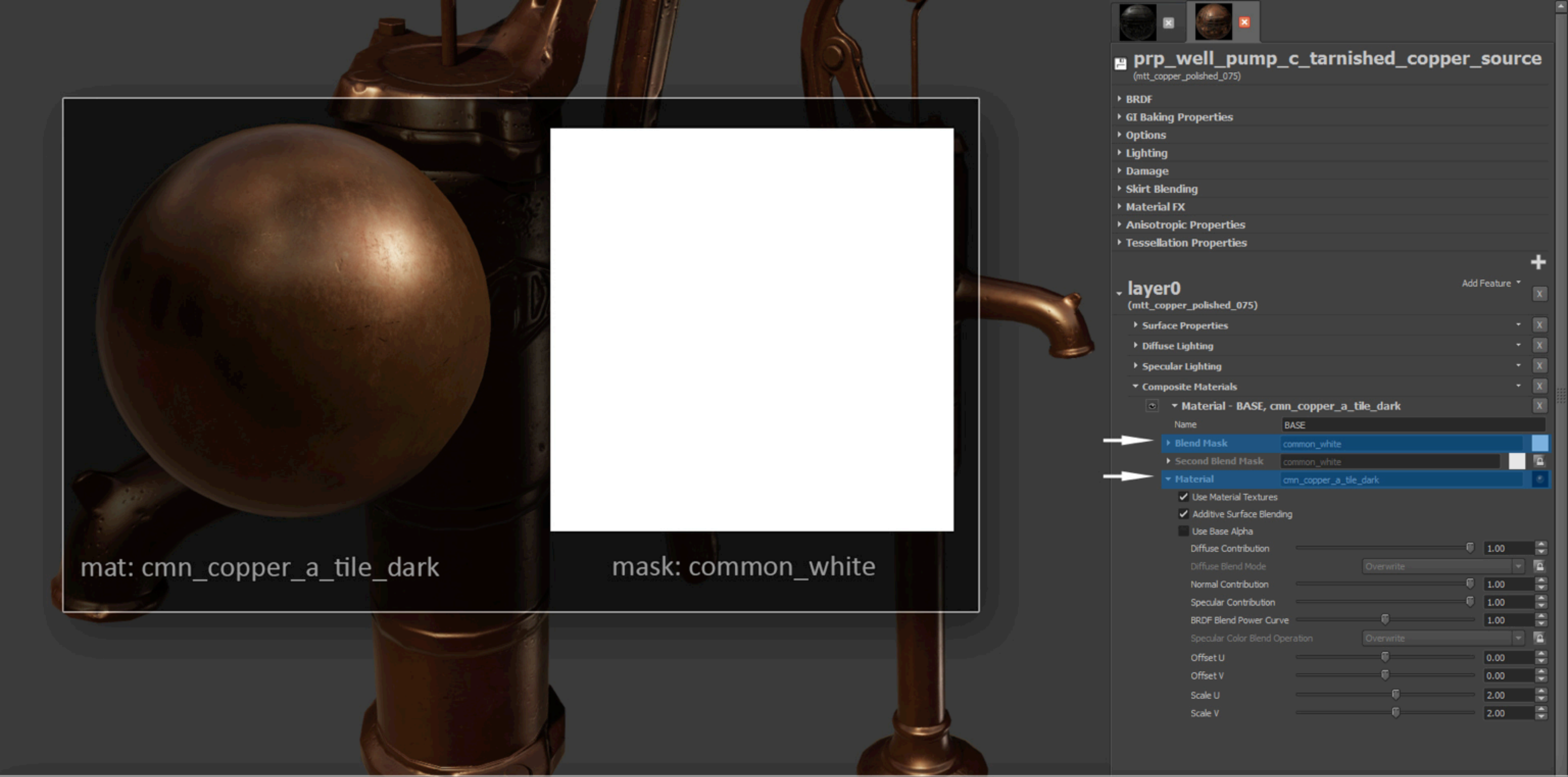


The artist then adds one composite layer, using a generic solid white mask as default



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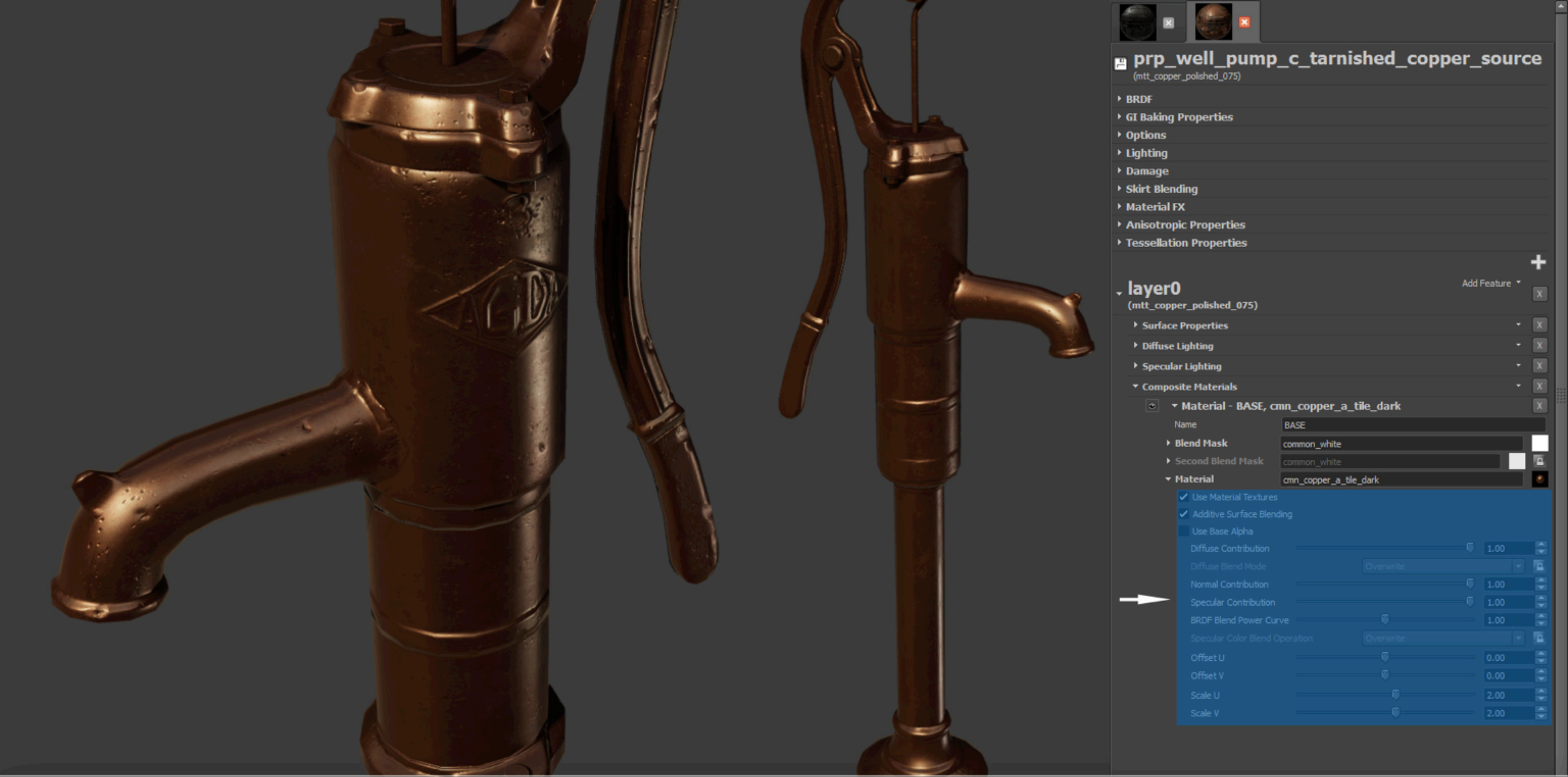
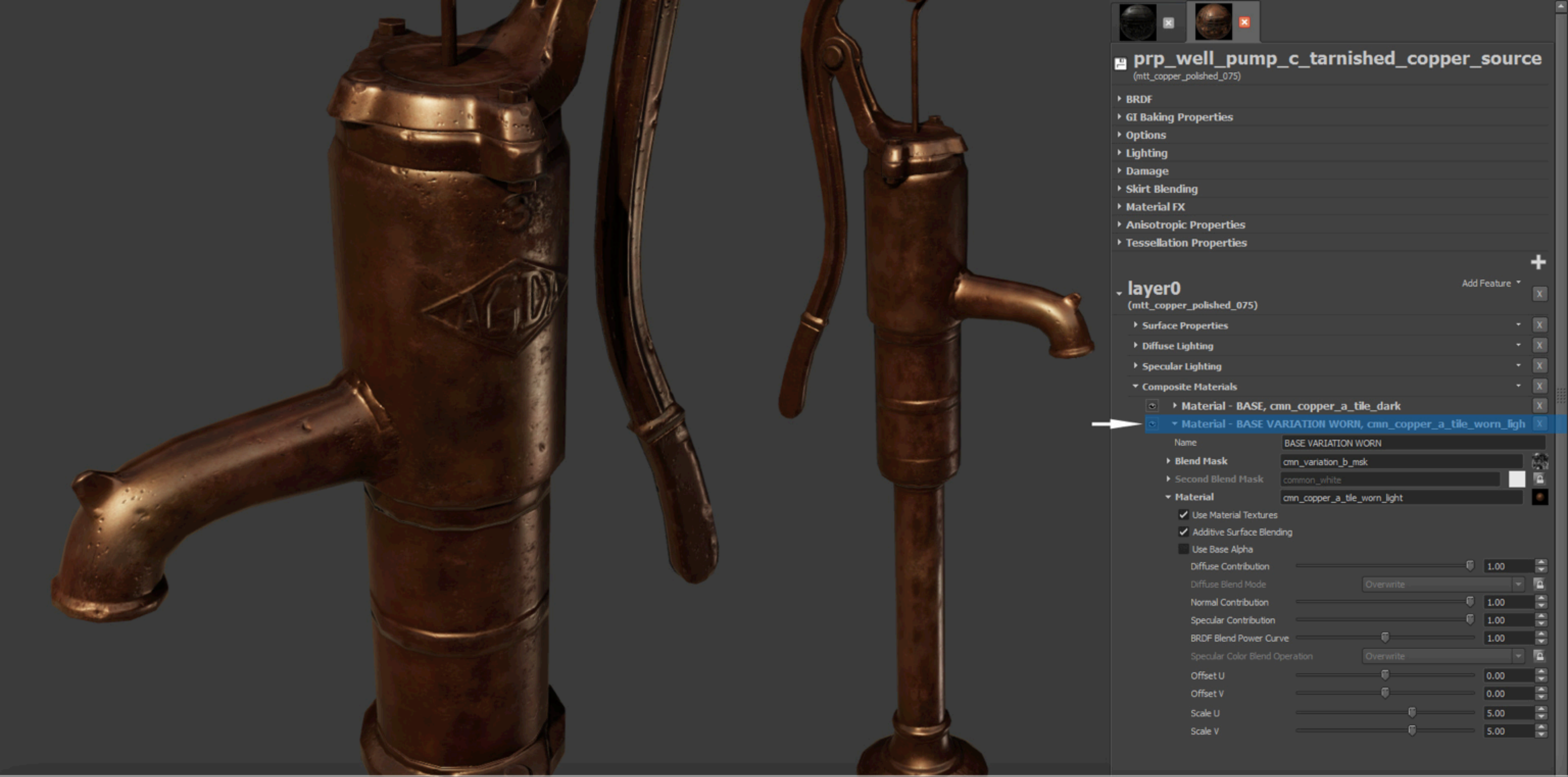
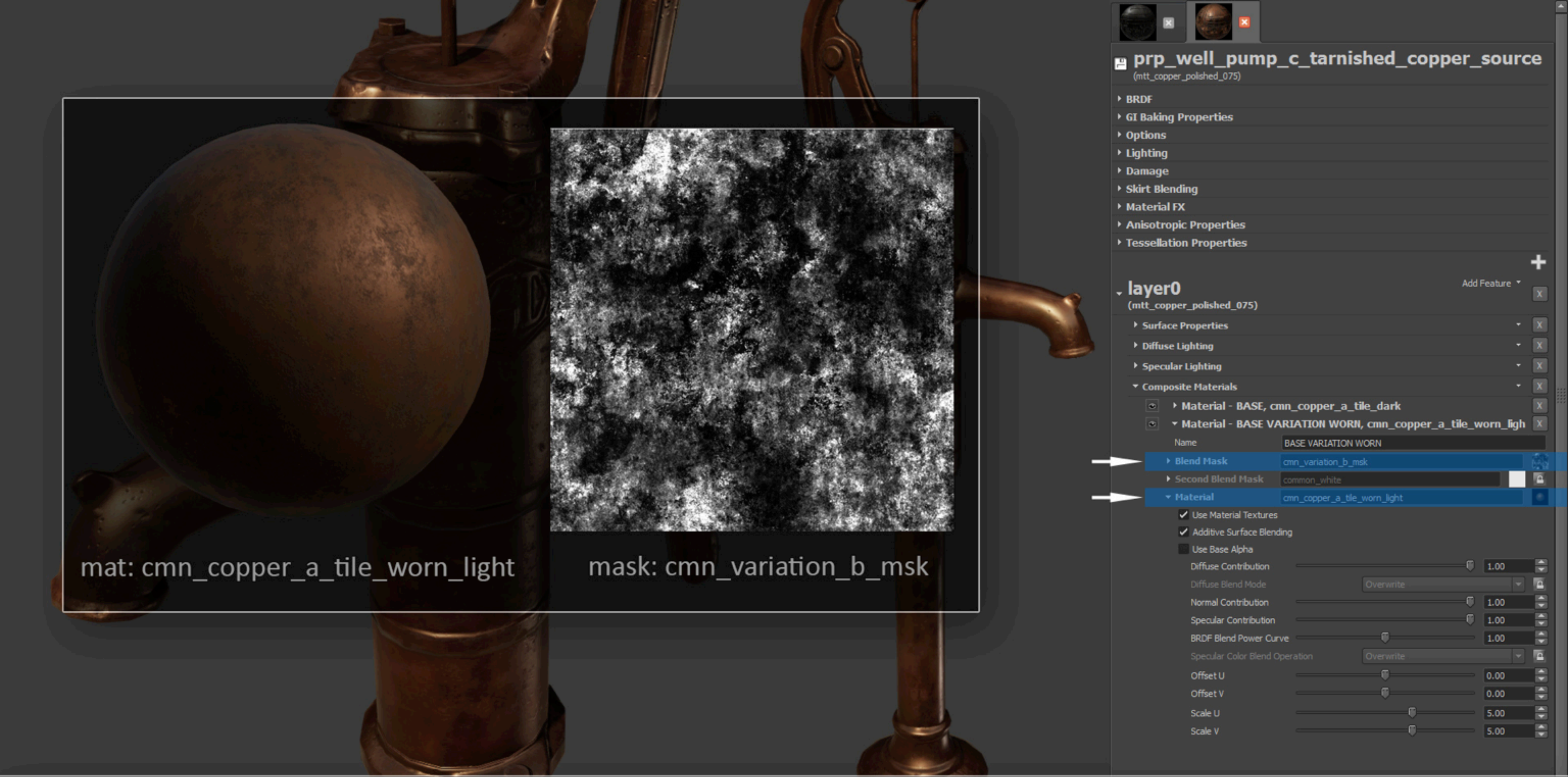


blend parameters such as additive surface, scaling, and per-pass contribution can be adjusted



A second composite layer is then added, using a worn copper material and existing generic mask



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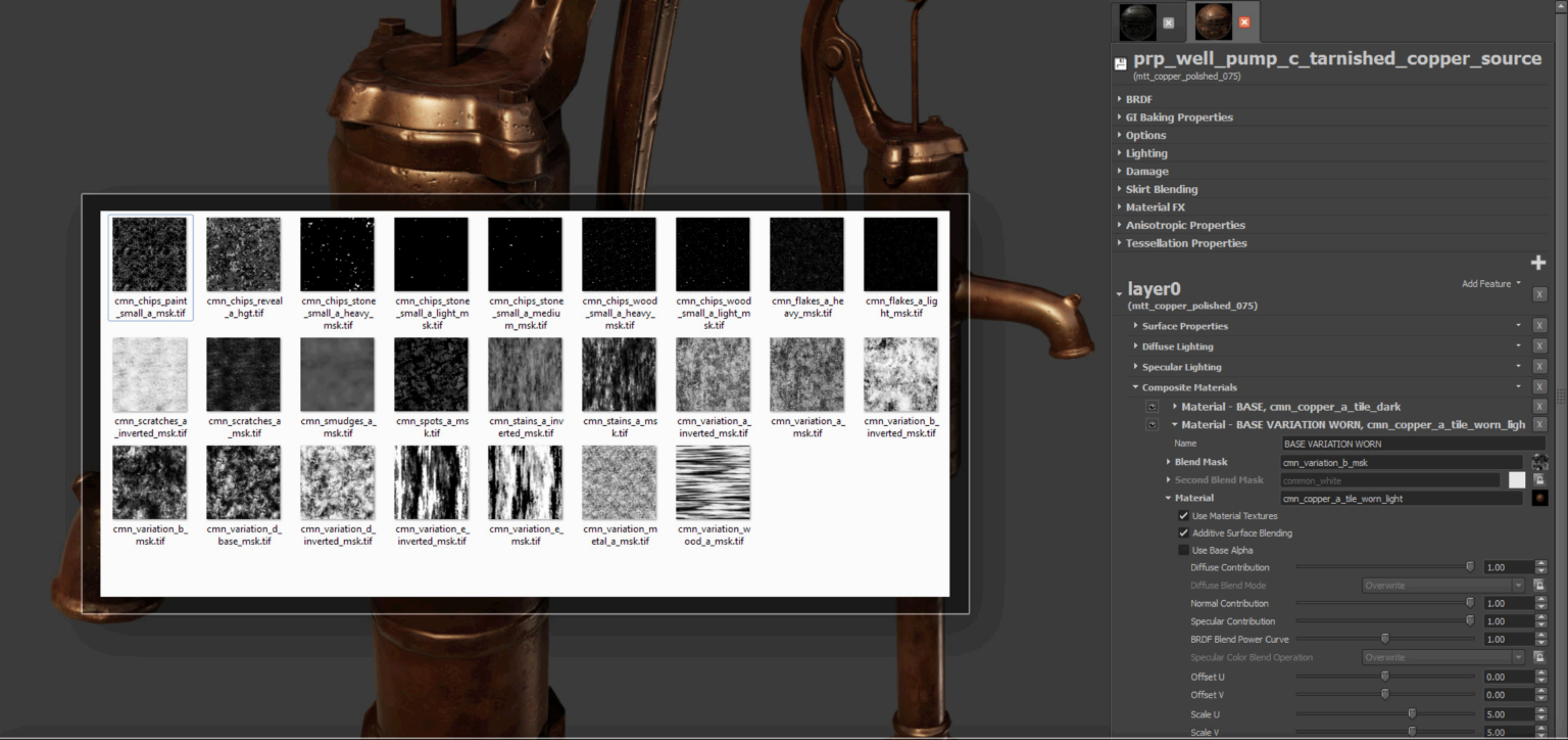
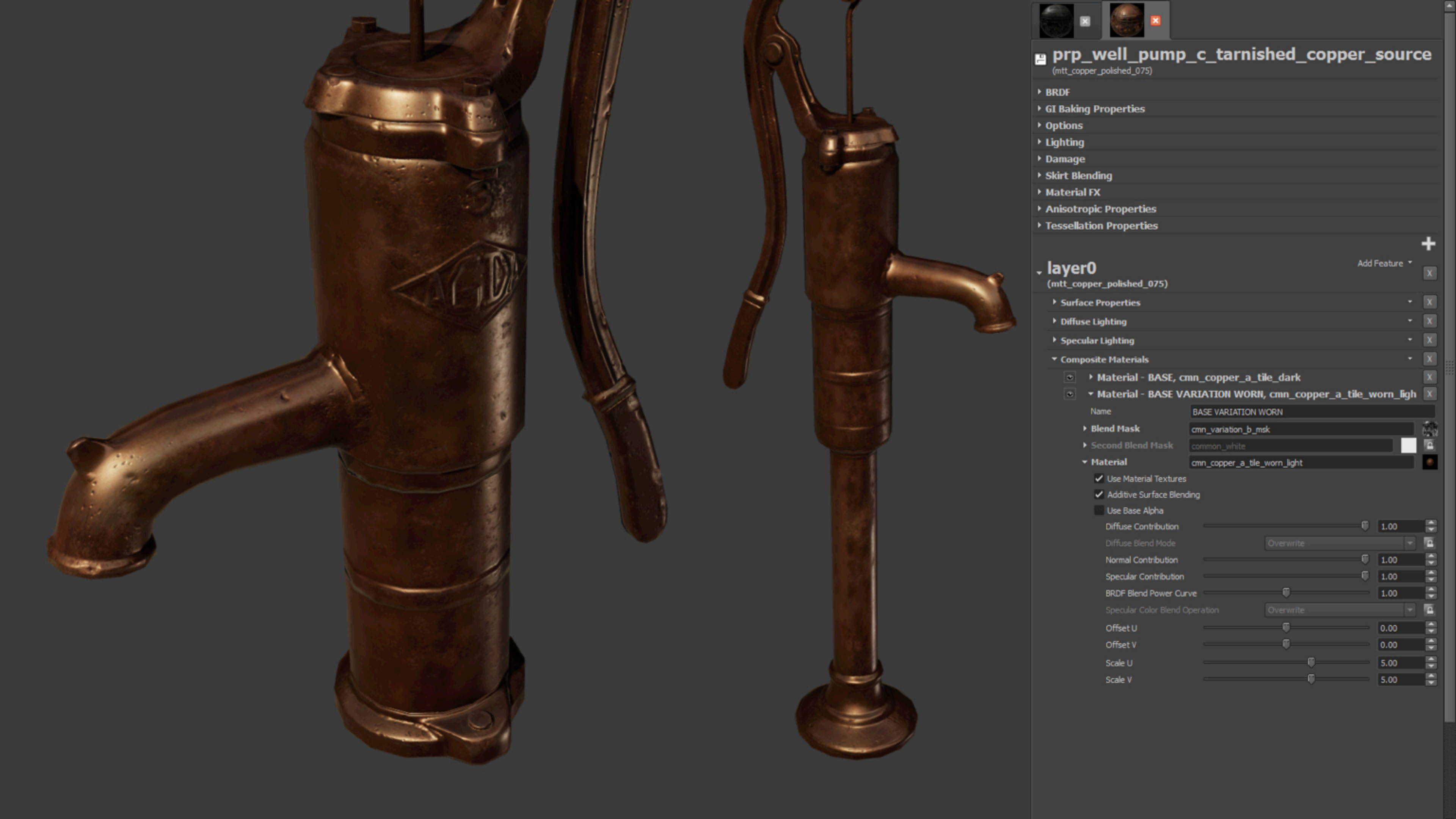


Many other generic masks are maintained in the common texture library

These can be used directly in the material editor as variation maps in the compositing stack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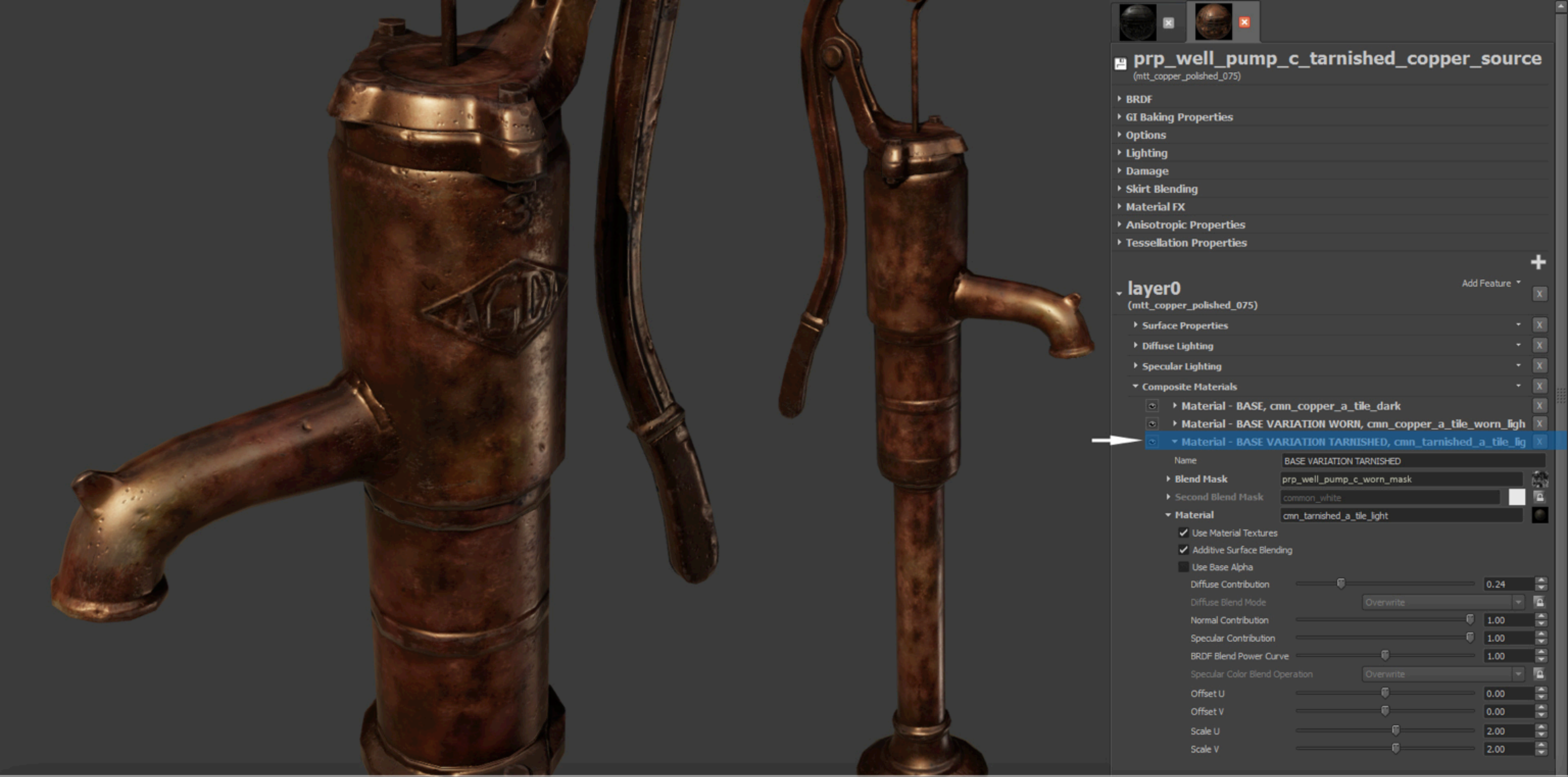
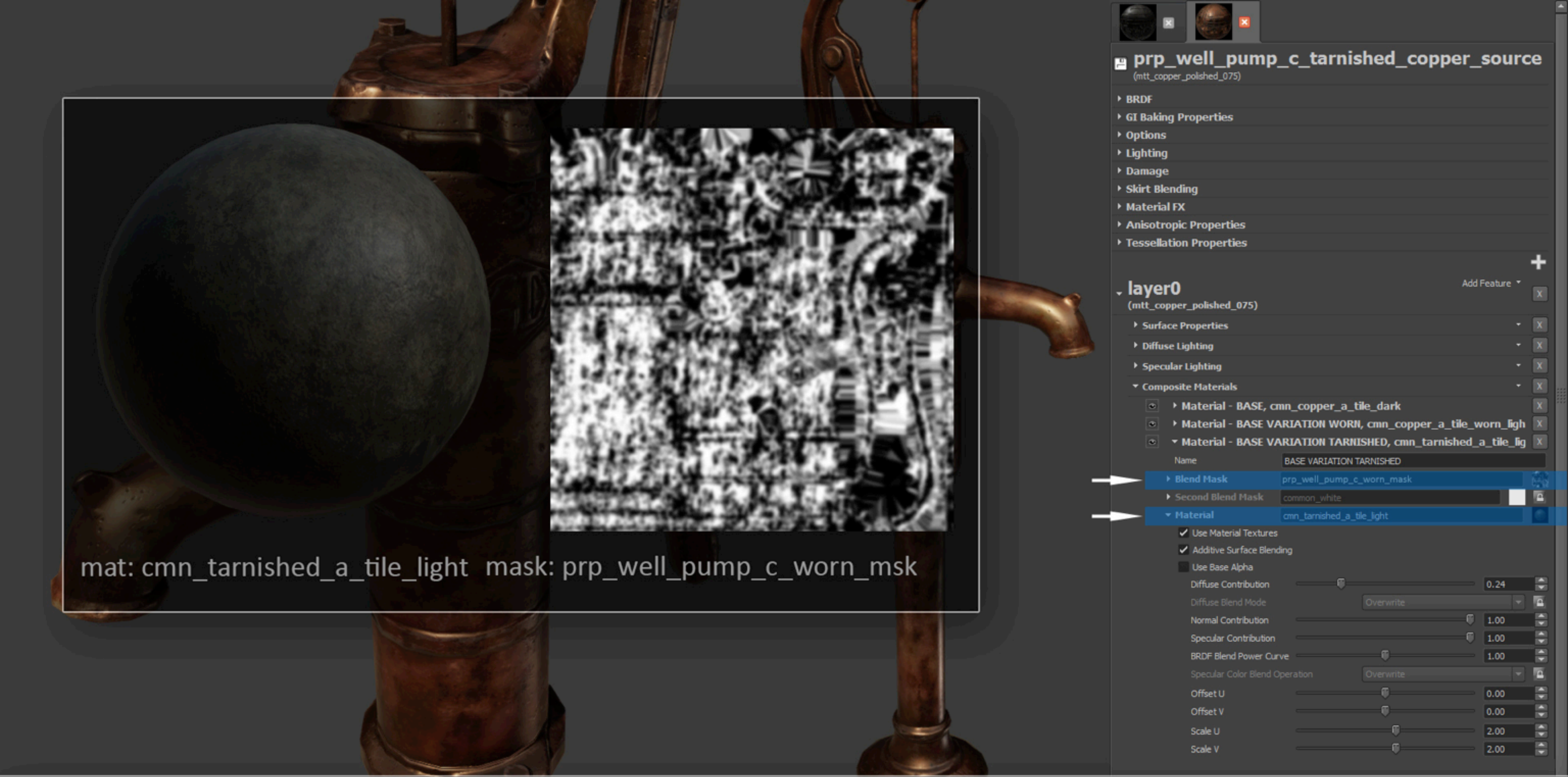
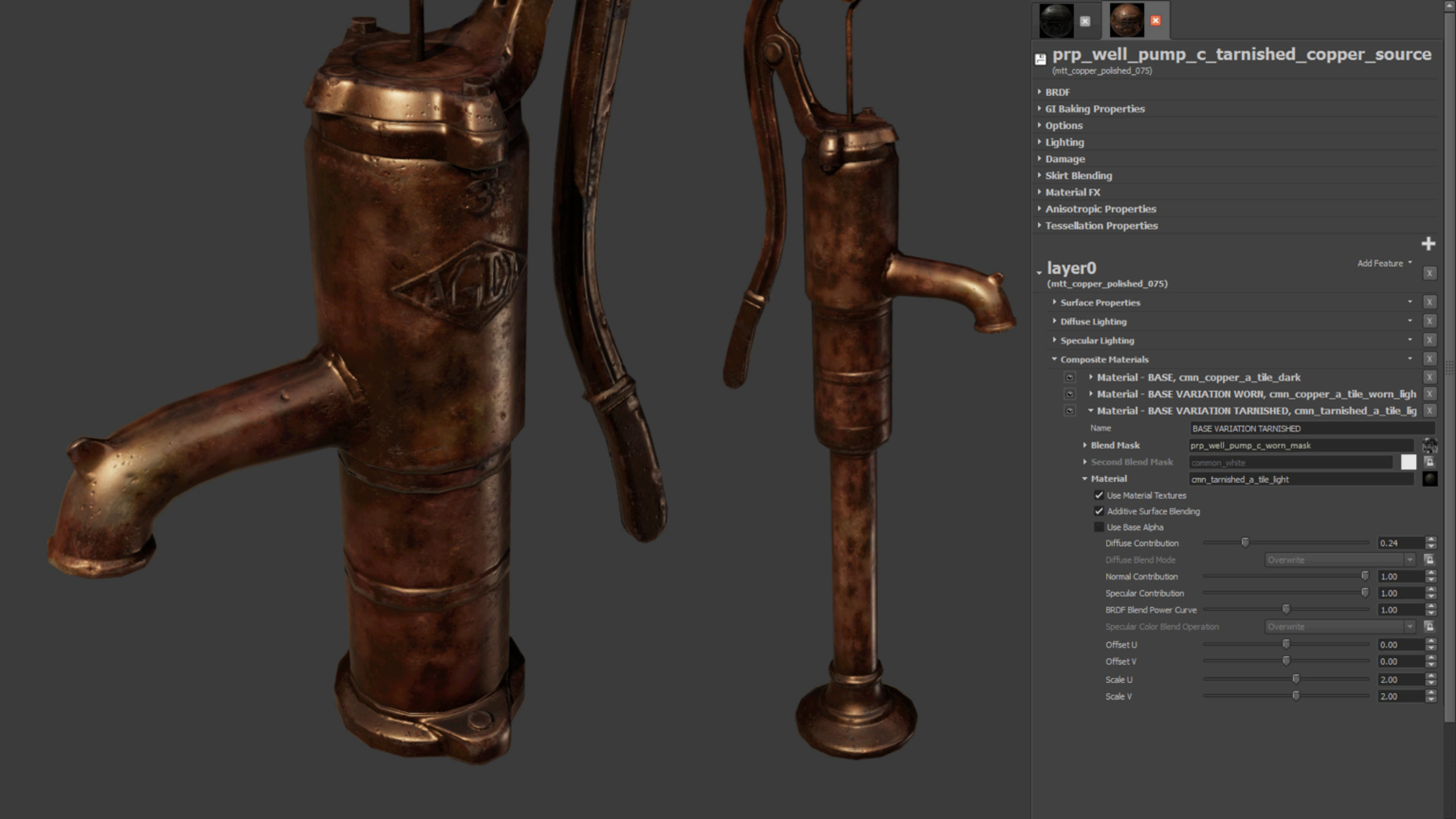
(mtt_copper_polished_075)
BRDF
GI Baking Properties
Options
Lighting
Damage
Skirt Blending
Material FX
Anisotropic Properties
Tessellation Properties
Add Feature
layer0
(mtt_copper_polished_075)
Surface Properties
Diffuse Lighting
Specular Lighting
Composite Materials
Material - BASE, cmn_copper_a_tile_dark
Material - BASE VARIATION WORN, cmn_copper_a_tile_worn_ligh
Name
BASE VARIATION WORN
Blend Mask
cmn_variation_b_msk
Second Blend Mask
common_white
Material
cmn_copper_a_tile_worn_light
Use Material Textures
Additive Surface Blending
Use Base Alpha
Diffuse Contribution 1.00
Diffuse Blend Mode Overwrite
Normal Contribution 1.00
Specular Contribution 1.00
BRDF Blend Power Curve 1.00
Specular Color Blend Operation Overwrite
Offset U 0.00
Offset V 0.00
Scale U 5.00
Scale V 5.00



Another composite layer is added for further wear



This mask is tailored for the prop, using the baked support maps as channels in Mari for 3d paint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(mtt_copper_polished_075)
BRDF
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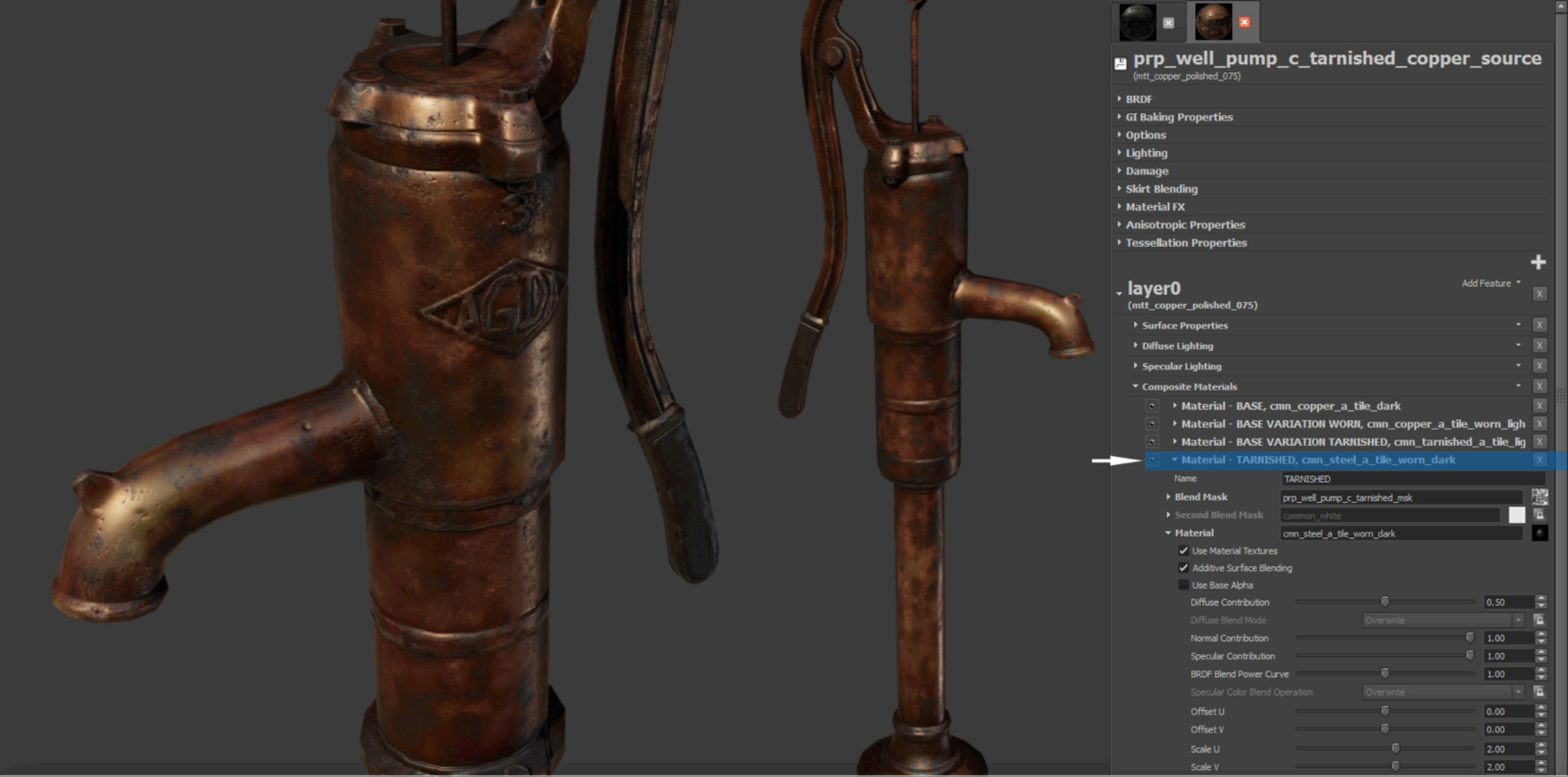
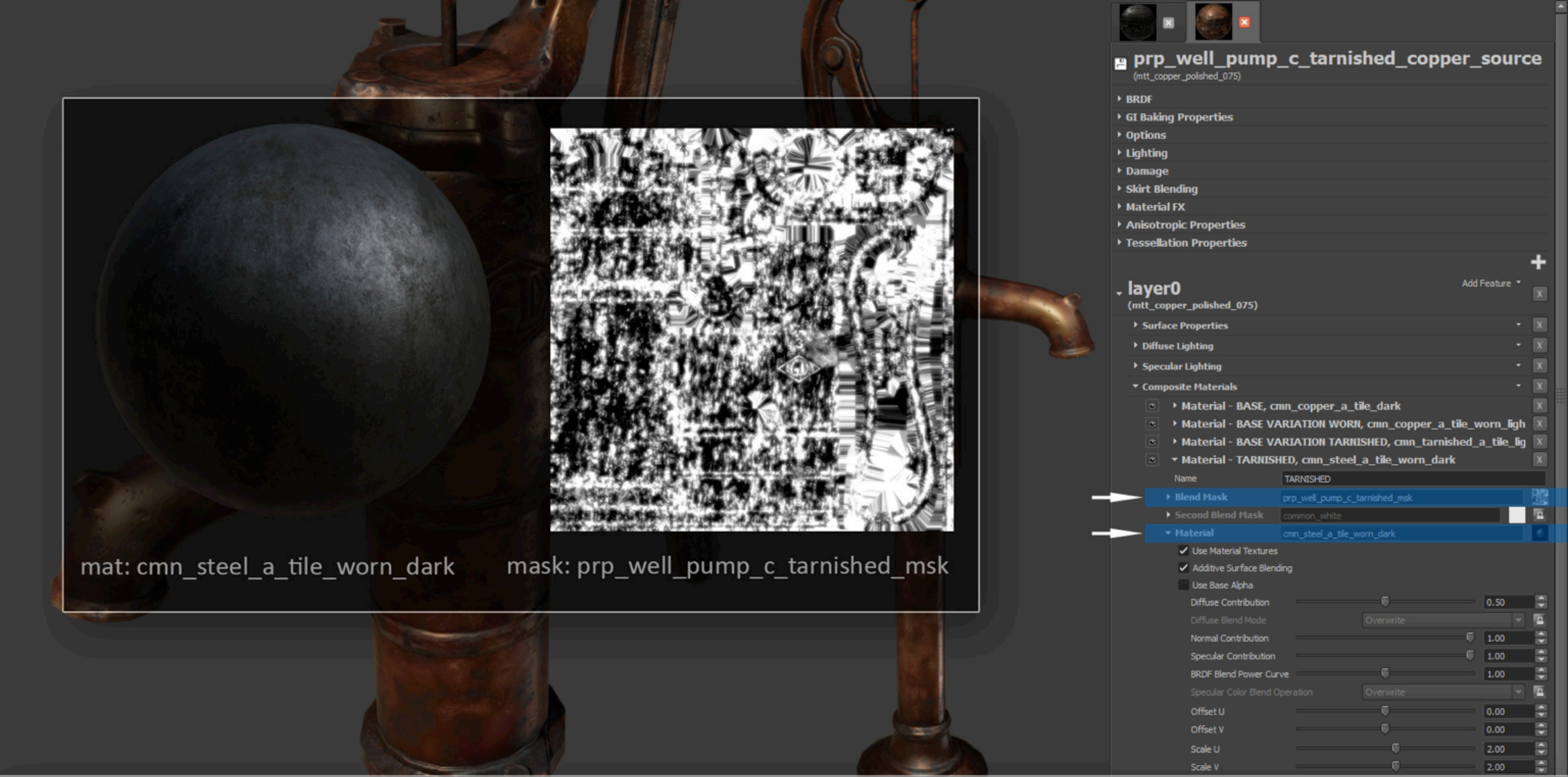
(mtt_copper_polished_075)
Surface Properties
Diffuse Lighting
Specular Lighting
Composite Materials
Material - BASE, cmn_copper_a_tile_dark
Material - BASE VARIATION WORN, cmn_copper_a_tile_worn_ligh
Material - BASE VARIATION TARNISHED, cmn_tarnished_a_tile_lig
Name
BASE VARIATION TARNISHED
Blend Mask
prp_well_pump_c_worn_mask
Second Blend Mask
common_white
Material
cmn_tarnished_a_tile_light
Use Material Textures
Additive Surface Blending
Use Base Alpha
Diffuse Contribution
0.24
Diffuse Blend Mode
Overwrite
Normal Contribution
1.00
Specular Contribution
1.00
BRDF Blend Power Curve
1.00
Specular Color Blend Operation
Overwrite
Offset U
0.00
Offset V
0.00
Scale U
2.00
Scale V
2.00



Another composite of a more worn metal is used to further eat away into the tarnished areas



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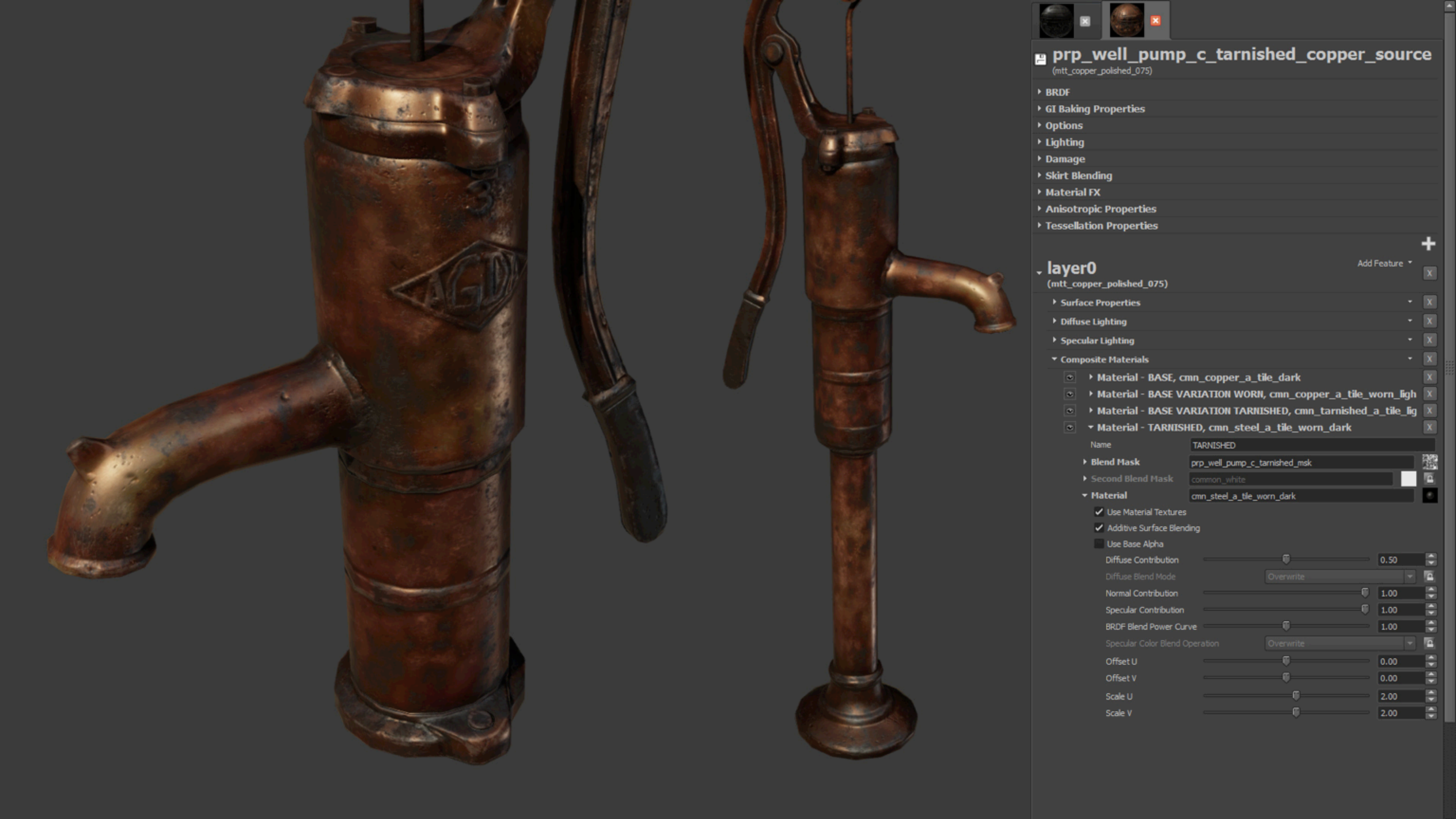
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Skirt Blending
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Composite Materials
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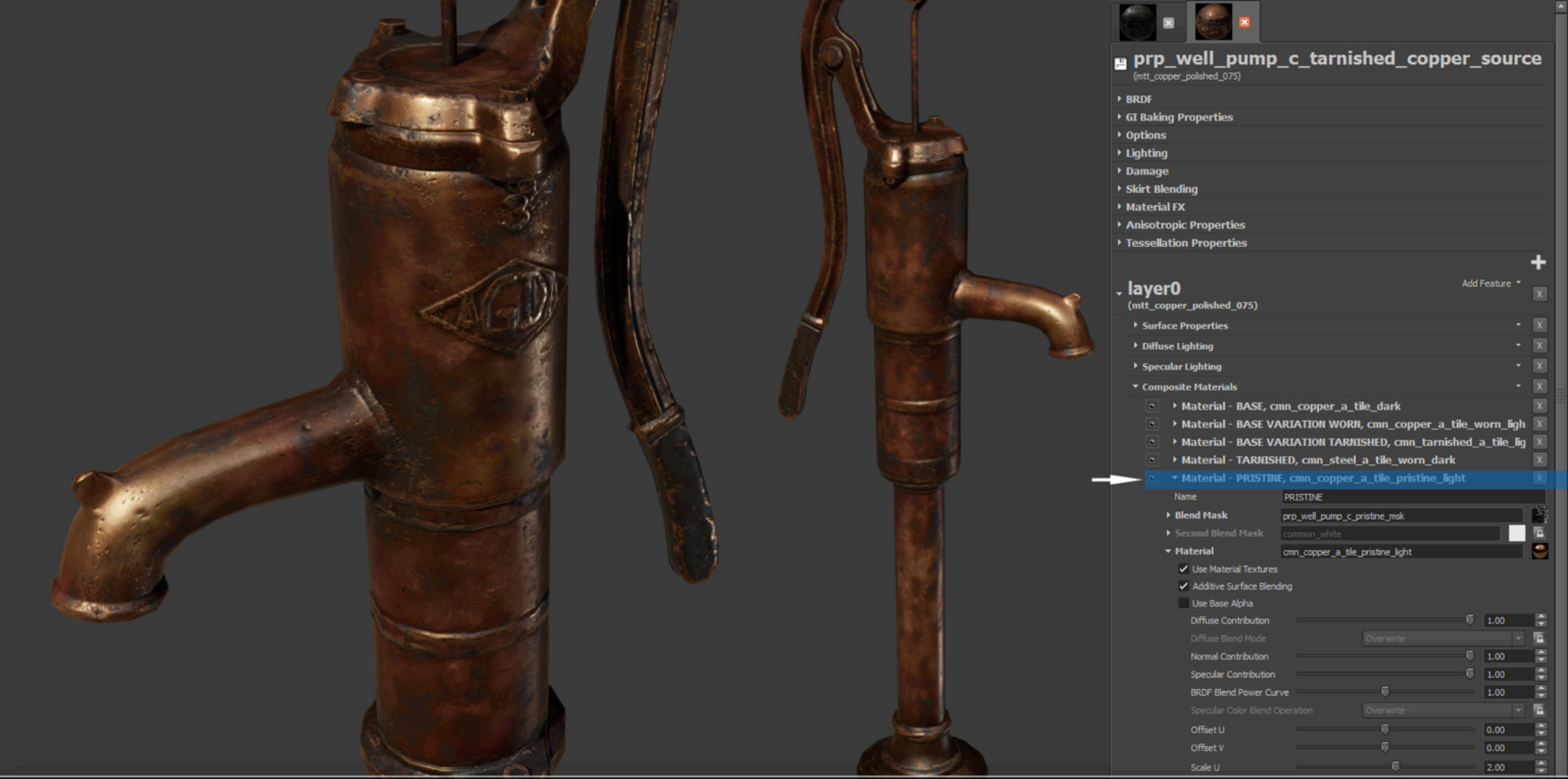
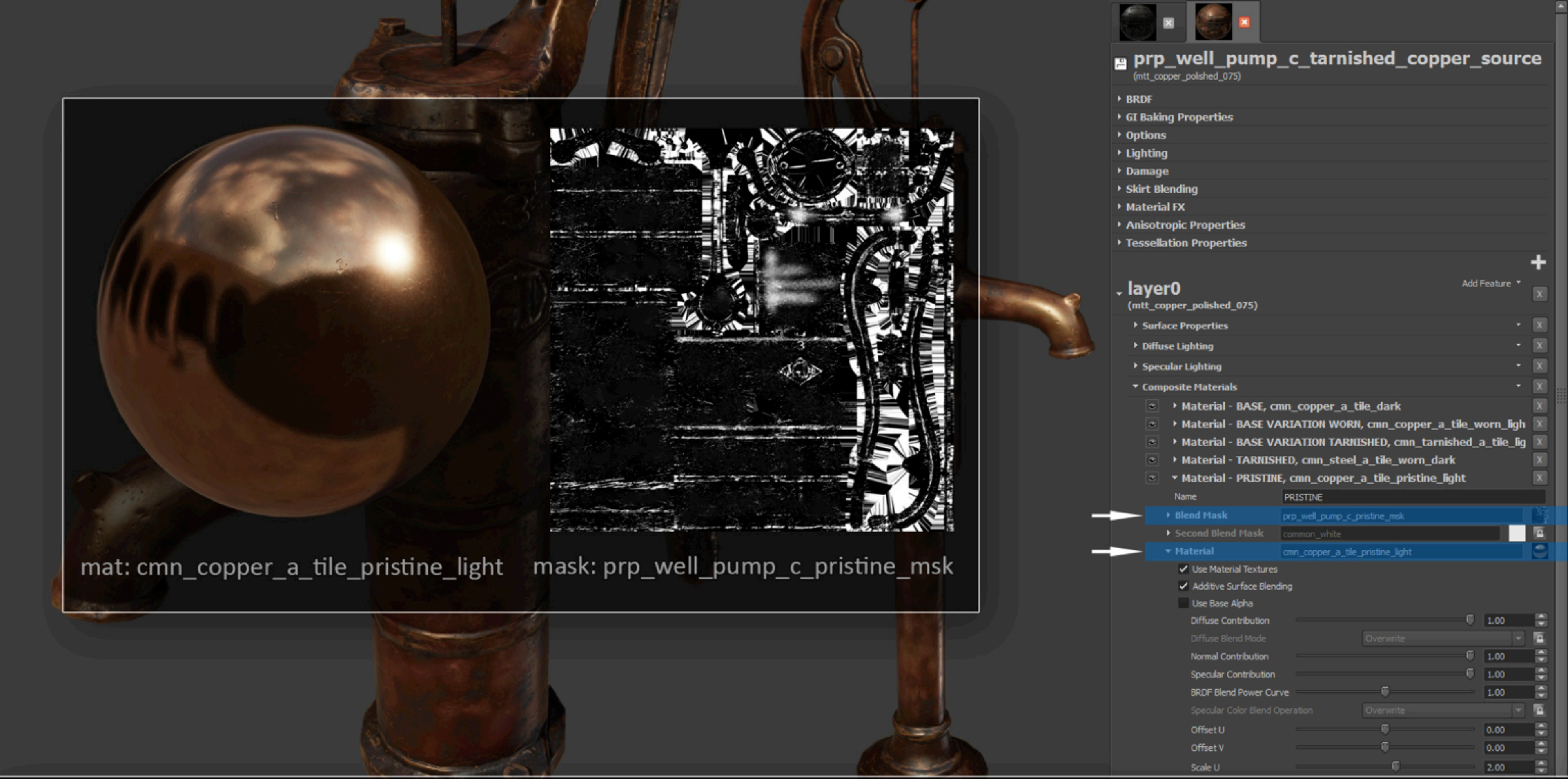
Material - BASE VARIATION WORN, cmn_copper_a_tile_worn_ligh
Material - BASE VARIATION TARNISHED, cmn_tarnished_a_tile_lig
Material - TARNISHED, cmn_steel_a_tile_worn_dark
Name
TARNISHED
Blend Mask
prp_well_pump_c_tarnished_msk
Second Blend Mask
common_white
Material
cmn_steel_a_tile_worn_dark
Use Material Textures
Additive Surface Blending
Use Base Alpha
Diffuse Contribution
0.50
Diffuse Blend Mode
Overwrite
Normal Contribution
1.00
Specular Contribution
1.00
BRDF Blend Power Curve
1.00
Specular Color Blend Operation
Overwrite
Offset U
0.00
Offset V
0.00
Scale U
2.00
Scale V
2.00



Recent scratches are indicated by another custom Mari mask, linked to a pristine copper



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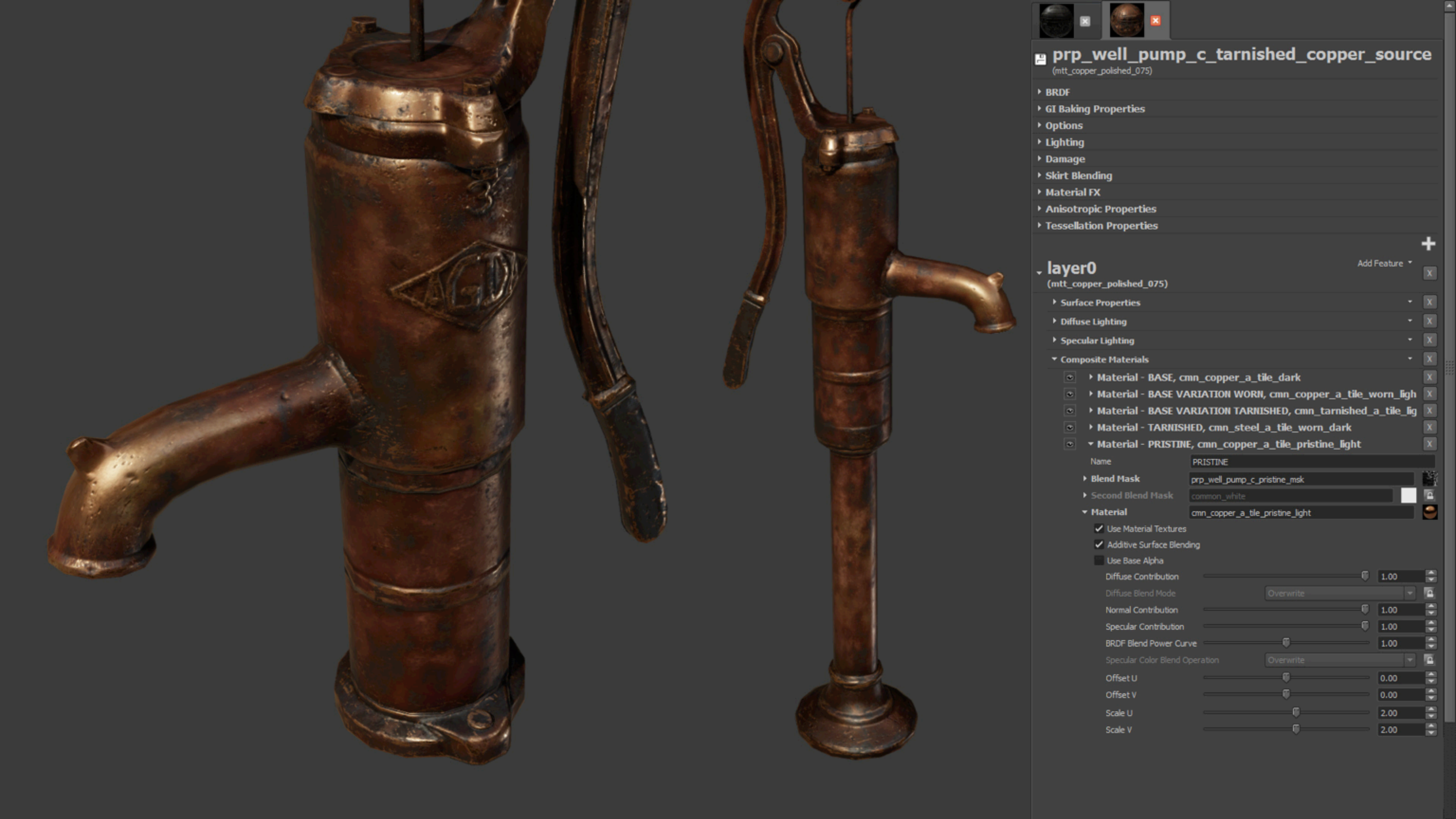
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(mtt_copper_polished_075)
BRDF
GI Baking Properties
Options
Lighting
Damage
Skirt Blending
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Surface Properties
Diffuse Lighting
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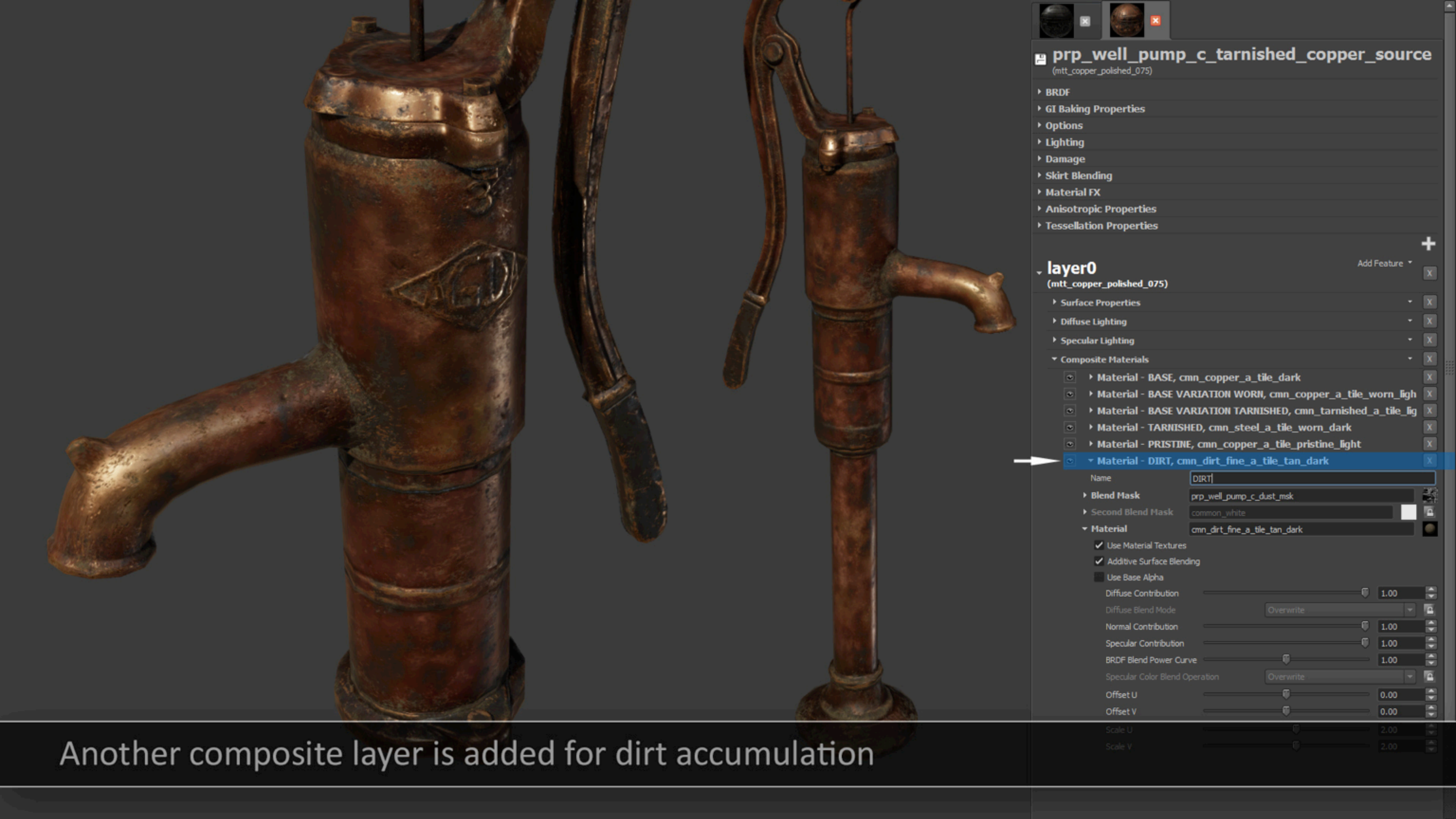
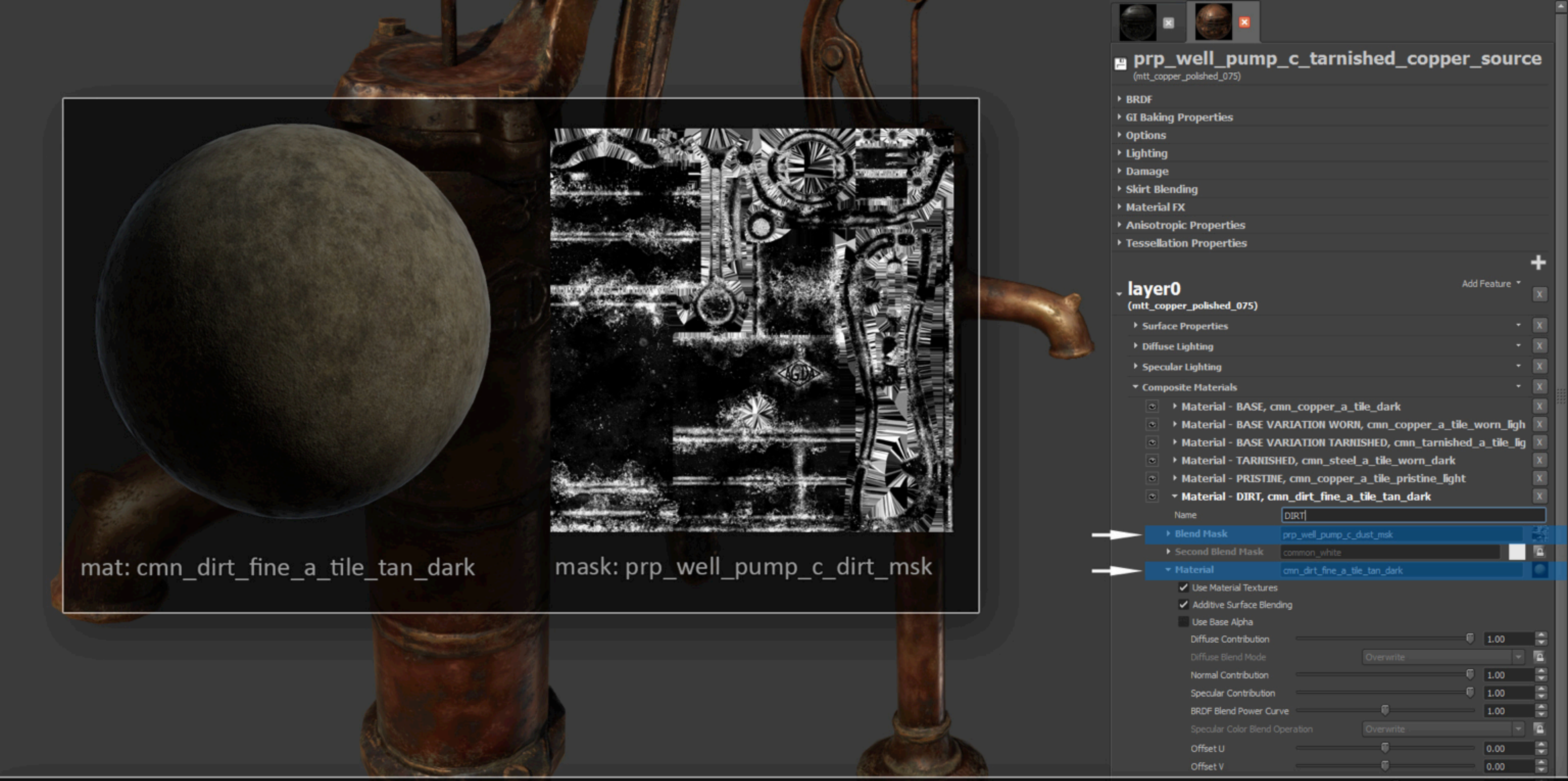
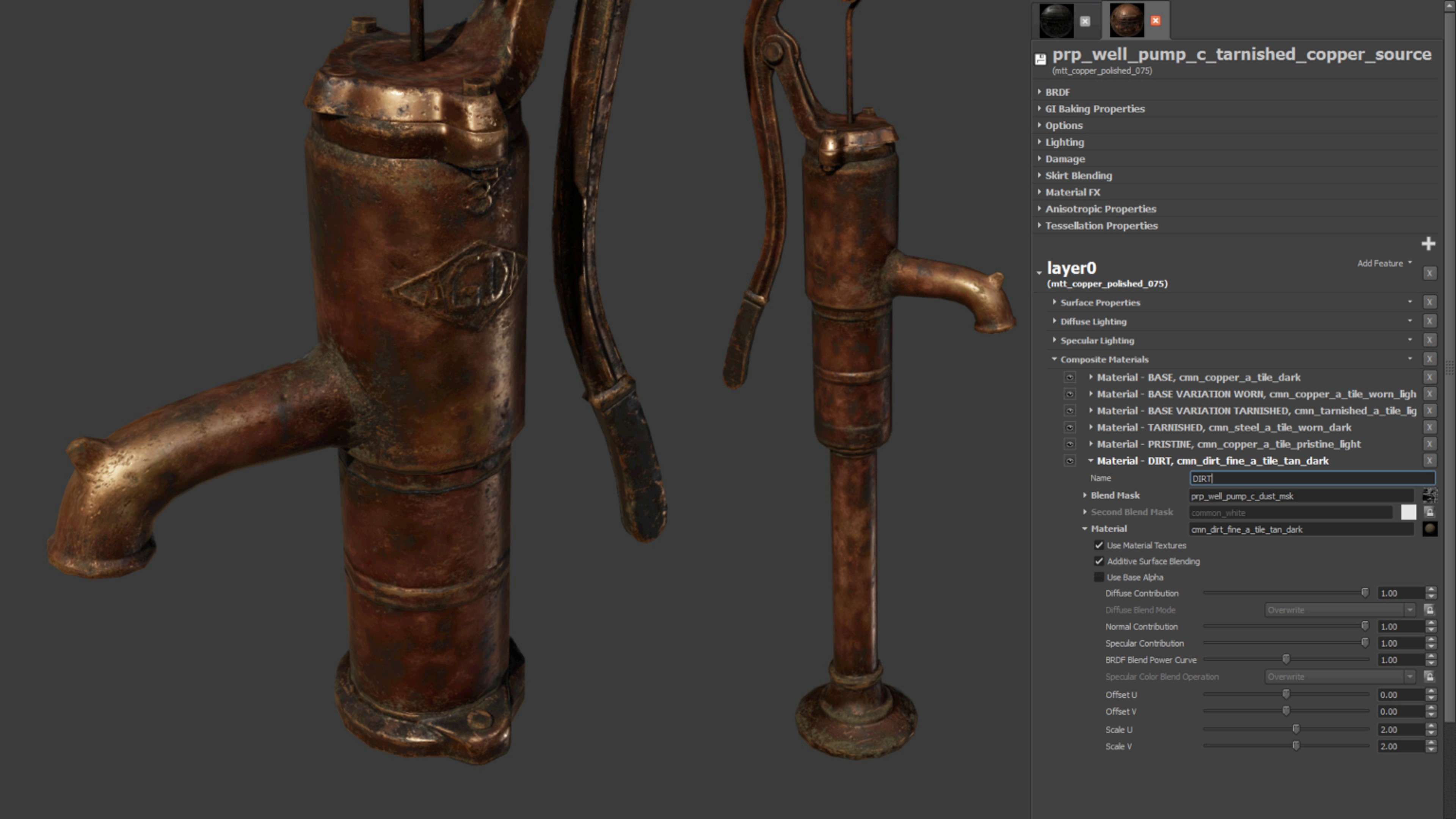
Material - BASE VARIATION WORN, cmn_copper_a_tile_worn_ligh
Material - BASE VARIATION TARNISHED, cmn_tarnished_a_tile_lig
Material - TARNISHED, cmn_steel_a_tile_worn_dark
Material - PRISTINE, cmn_copper_a_tile_pristine_light
Name PRISTINE
Blend Mask prp_well_pump_c_pristine_msk
Second Blend Mask common_white
Material cmn_copper_a_tile_pristine_light
Use Material Textures
Additive Surface Blending
Use Base Alpha
Diffuse Contribution 1.00
Diffuse Blend Mode Overwrite
Normal Contribution 1.00
Specular Contribution 1.00
BRDF Blend Power Curve 1.00
Specular Color Blend Operation Overwrite
Offset U 0.00
Offset V 0.00
Scale U 2.00
Scale V 2.00

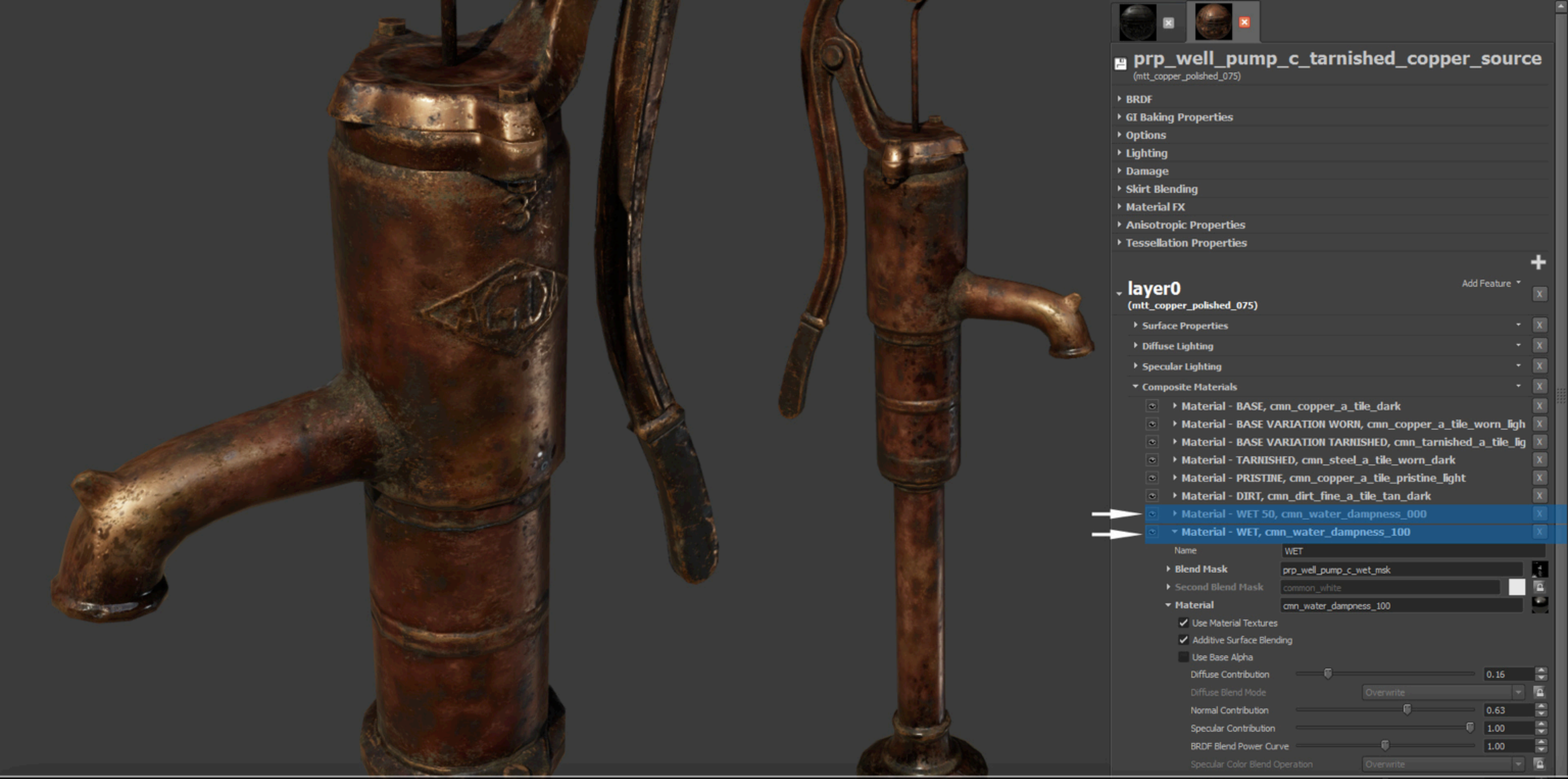


Another composite layer is added for dirt accumulation

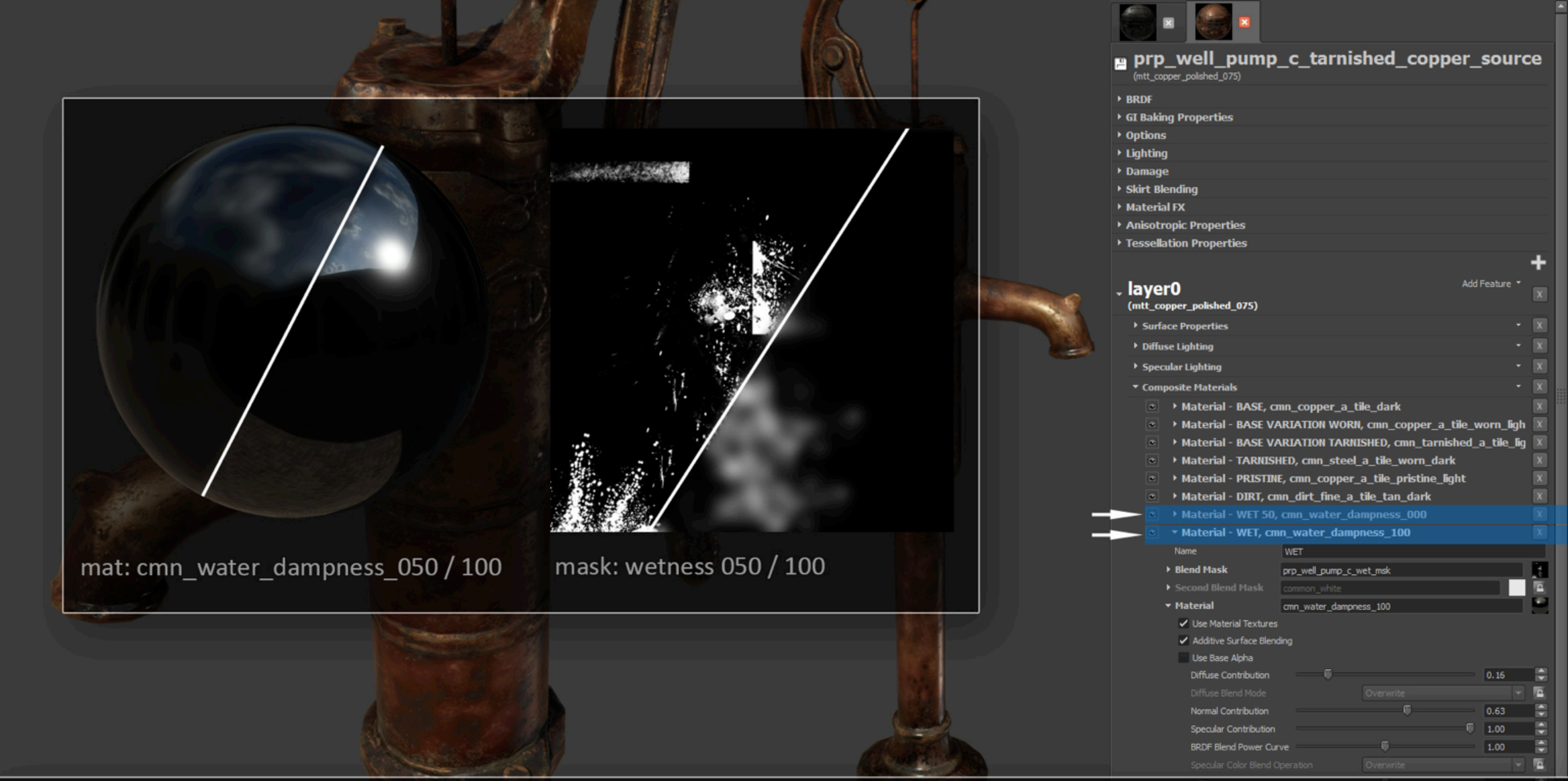


Another composite layer is added for dirt accumulation

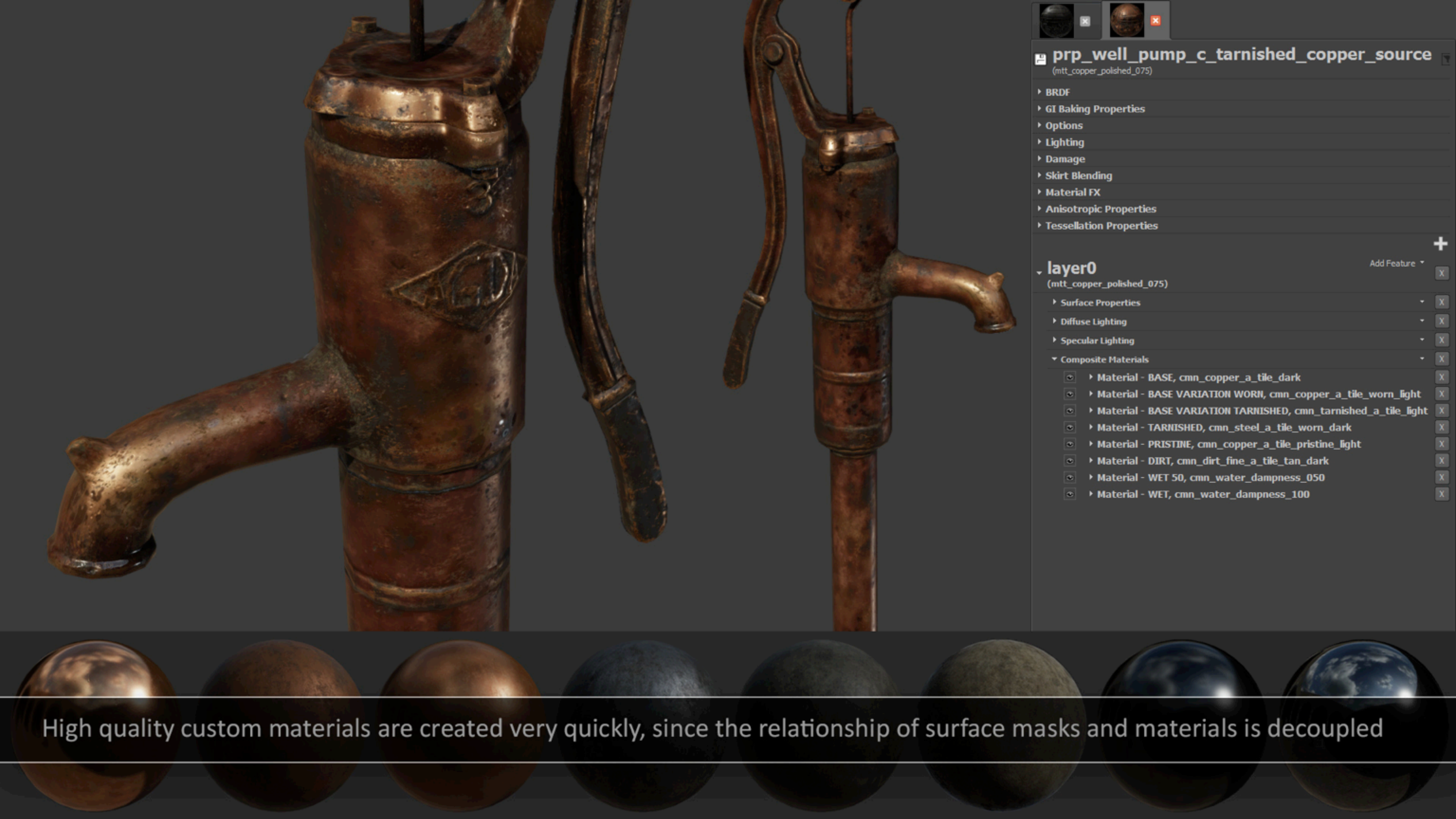

prp_well_pump_c_tarnished_copper_source
(mtt_copper_polished_075)
BRDF
GI Baking Properties
Options
Lighting
Damage
Skirt Blending
Material FX
Anisotropic Properties
Tessellation Properties
Add Feature
layer0
(mtt_copper_polished_075)
Surface Properties
Diffuse Lighting
Specular Lighting
Composite Materials
Material - BASE, cmn_copper_a_tile_dark
Material - BASE VARIATION WORN, cmn_copper_a_tile_worn_ligh
Material - BASE VARIATION TARNISHED, cmn_tarnished_a_tile_lig
Material - TARNISHED, cmn_steel_a_tile_worn_dark
Material - PRISTINE, cmn_copper_a_tile_pristine_light
Material - DIRT, cmn_dirt_fine_a_tile_tan_dark
Name
DIRT
Blend Mask
prp_well_pump_c_dust_msk
Second Blend Mask
common_white
Material
cmn_dirt_fine_a_tile_tan_dark
Use Material Textures
Additive Surface Blending
Use Base Alpha
Diffuse Contribution
1.00
Diffuse Blend Mode
Overwrite
Normal Contribution
1.00
Specular Contribution
1.00
BRDF Blend Power Curve
1.00
Specular Color Blend Operation
Overwrite
Offset U
0.00
Offset V
0.00
Scale U
2.00
Scale V
2.00



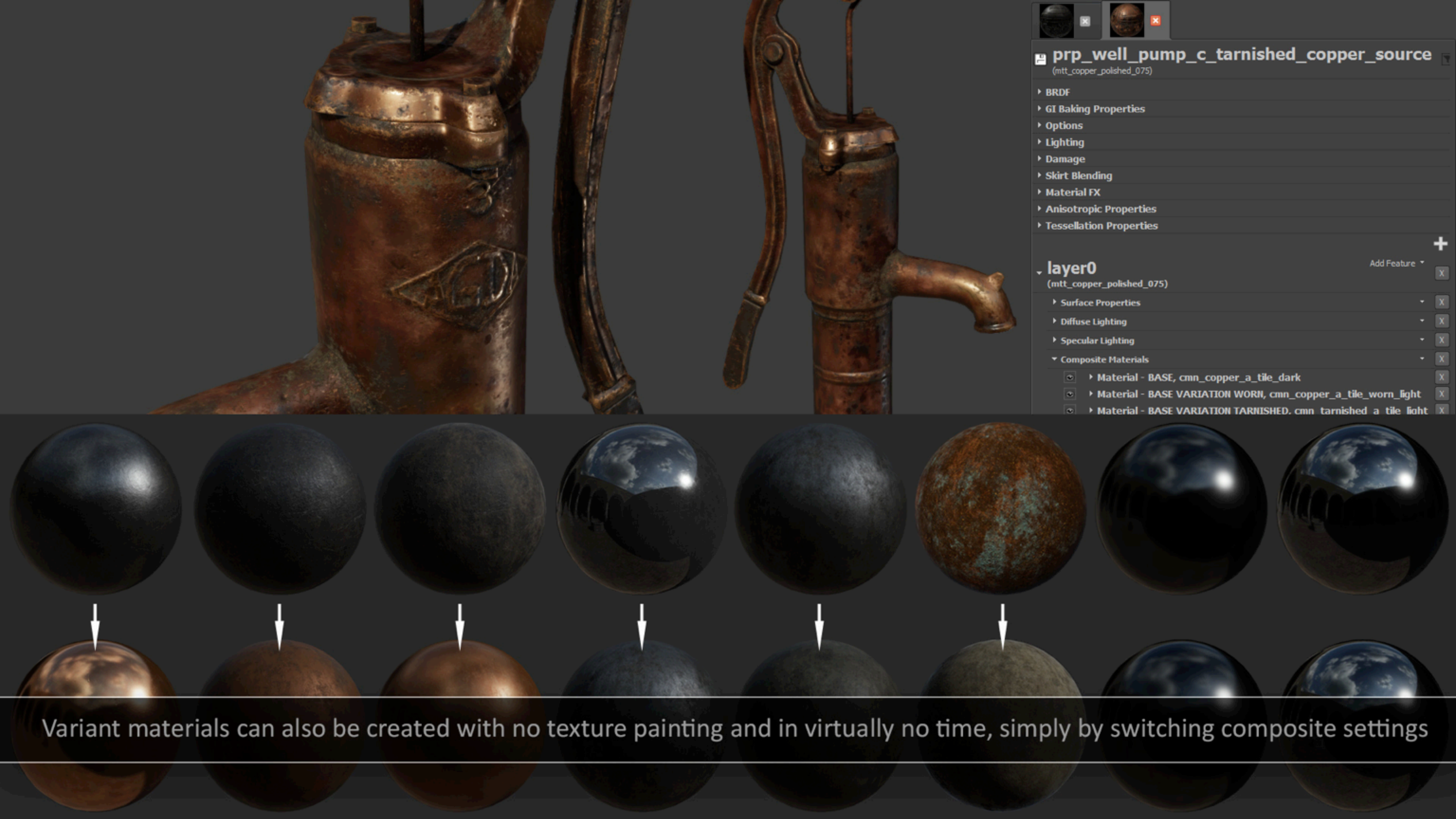
Wetness on the object is conveyed with two more composite layers and masks



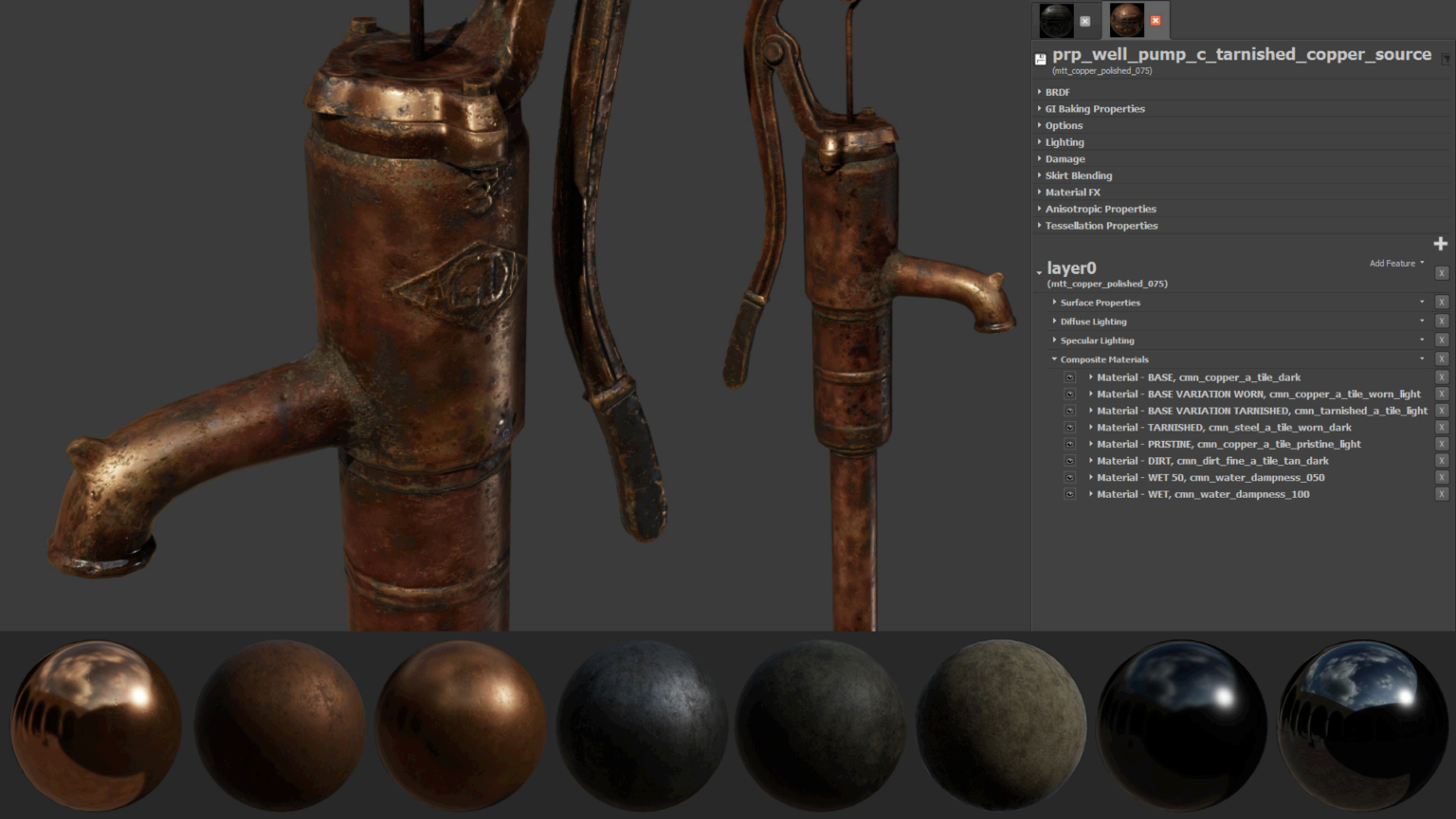
The first is broader and blurred for slight dampness, and the second is sharp for standing water

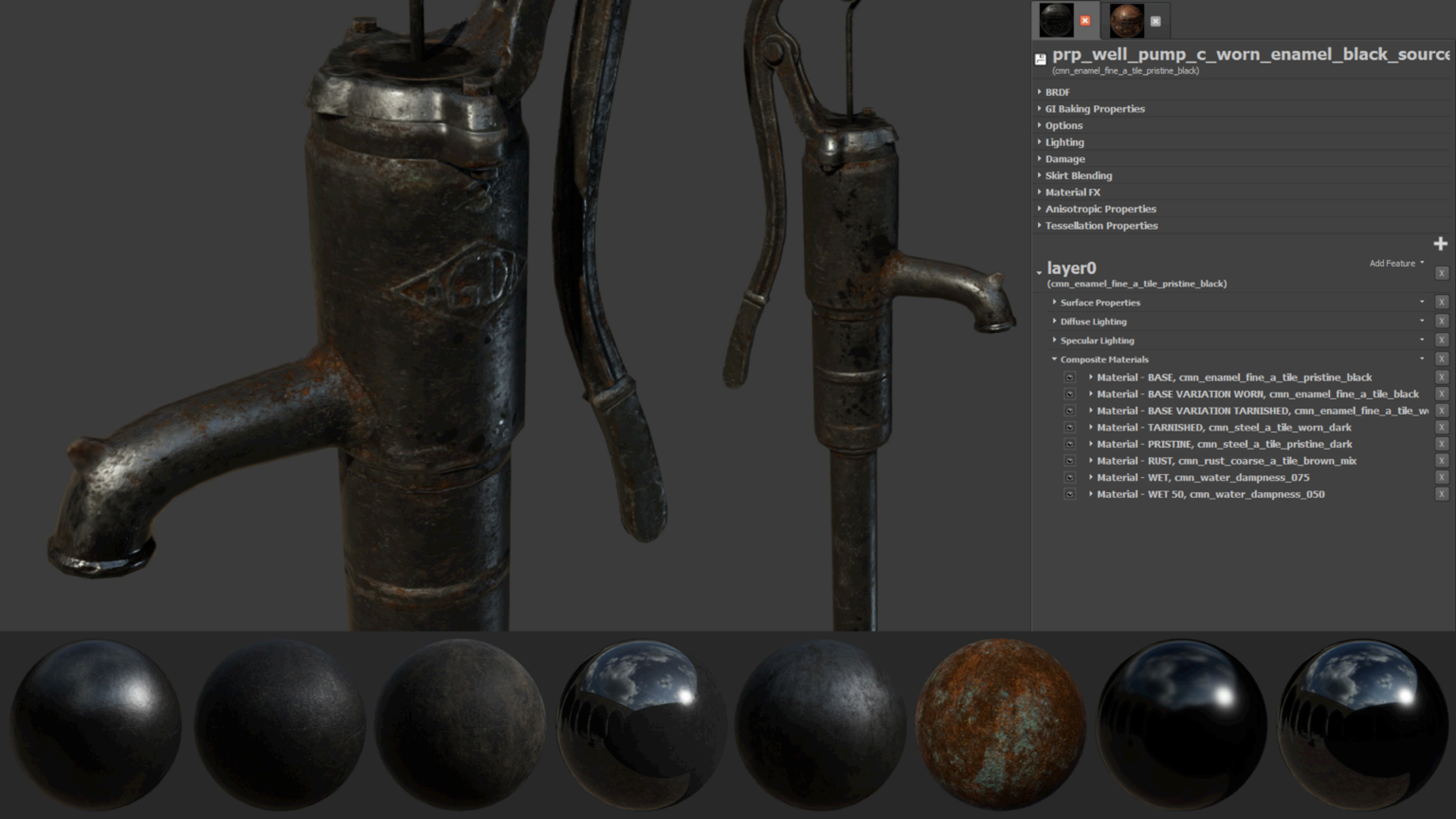


High quality custom materials are created very quickly, since the relationship of surface masks and materials is decoupled



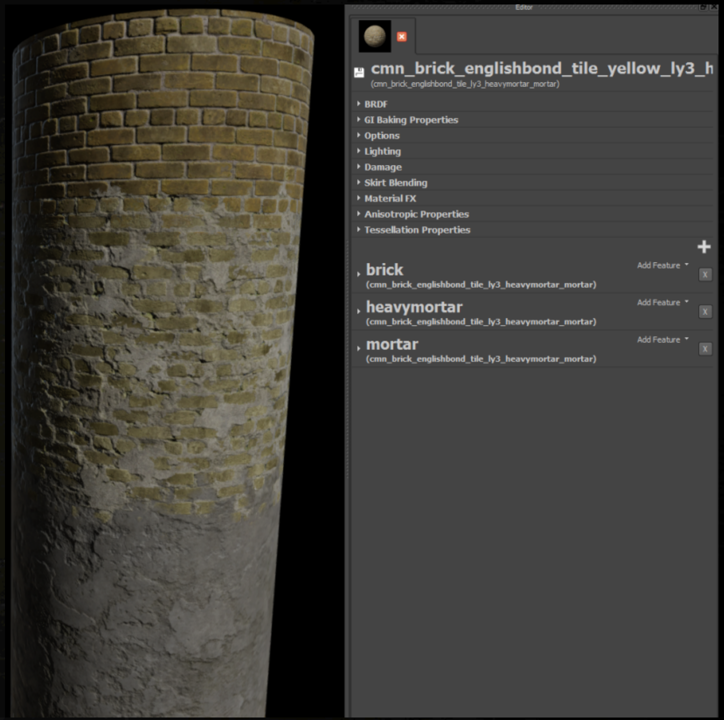
Variant materials can also be created with no texture painting and in virtually no time, simply by switching composite settings


prp_well_pump_c_tarnished_copper_source
(mtt_copper_polished_075)
BRDF
GI Baking Properties
Options
Lighting
Damage
Skirt Blending
Material FX
Anisotropic Properties
Tessellation Properties
Add Feature
layer0
(mtt_copper_polished_075)
Surface Properties
Diffuse Lighting
Specular Lighting
Composite Materials
Material - BASE, cmn_copper_a_tile_dark
Material - BASE VARIATION WORN, cmn_copper_a_tile_worn_light
Material - BASE VARIATION TARNISHED, cmn_tarnished_a_tile_light
Material - TARNISHED, cmn_steel_a_tile_worn_dark
Material - PRISTINE, cmn_copper_a_tile_pristine_light
Material - DIRT, cmn_dirt_fine_a_tile_tan_dark
Material - WET 50, cmn_water_dampness_050
Material - WET, cmn_water_dampness_100

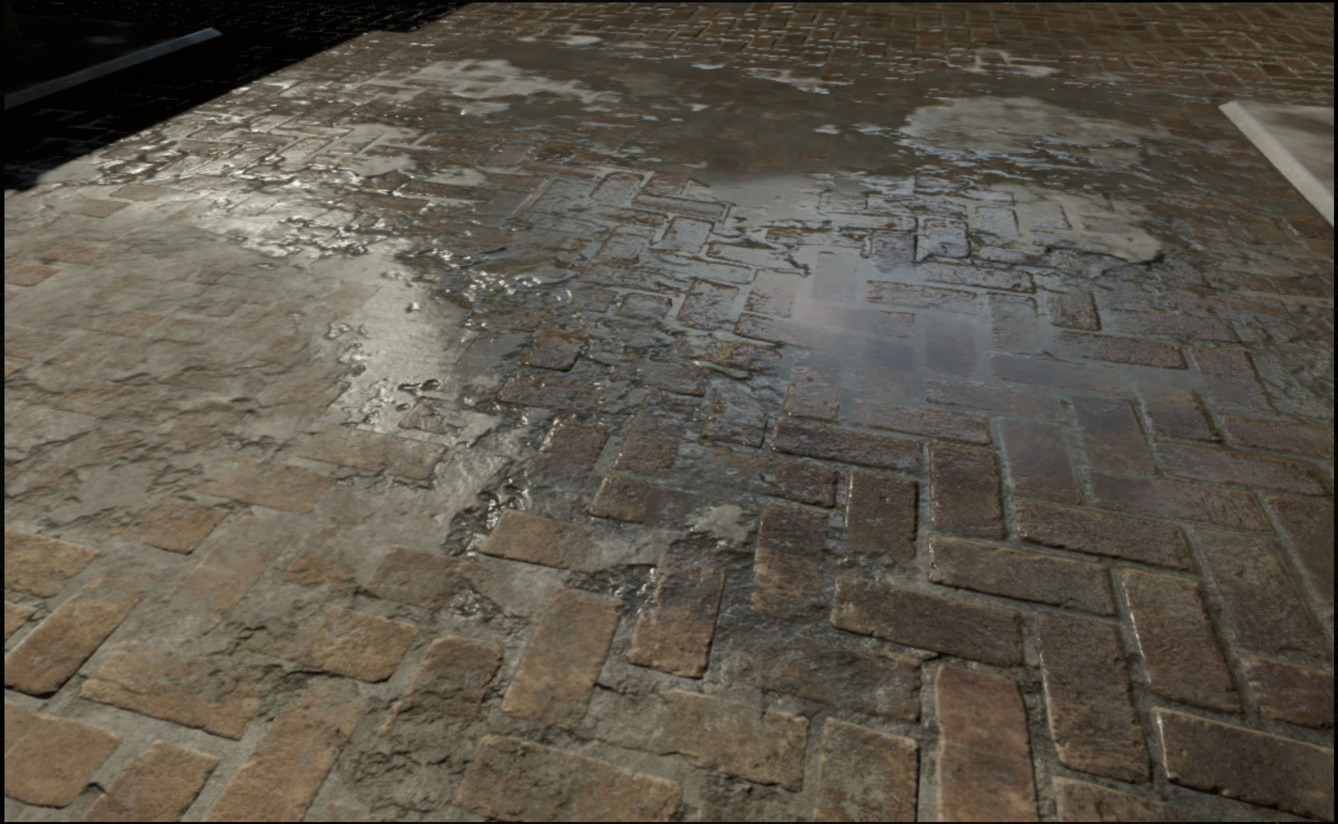

prp_well_pump_c_worn_enamel_black_source
(cmn_enamel_fine_a_tile_pristine_black)
BRDF
GI Baking Properties
Options
Lighting
Damage
Skirt Blending
Material FX
Anisotropic Properties
Tessellation Properties
Add Feature
layer0
(cmn_enamel_fine_a_tile_pristine_black)
Surface Properties
Diffuse Lighting
Specular Lighting
Composite Materials
Material - BASE, cmn_enamel_fine_a_tile_pristine_black
Material - BASE VARIATION WORN, cmn_enamel_fine_a_tile_black
Material - BASE VARIATION TARNISHED, cmn_enamel_fine_a_tile_w
Material - TARNISHED, cmn_steel_a_tile_worn_dark
Material - PRISTINE, cmn_steel_a_tile_pristine_dark
Material - RUST, cmn_rust_coarse_a_tile_brown_mix
Material - WET, cmn_water_dampness_075
Material - WET 50, cmn_water_dampness_050

Material Layers

- Up to 4 layers
  - Derived from base materials
  - Separate compositing chain per layer
  - Driven by vertex colors



Material Layers



Future Work

- Compositing of other BRDF types
- Cheaper compositing of multiple BRDFs
- Improved Specular AA approximations
- Multiple specular lobes
- Better diffuse BRDFs

Specular AA Sample App

- https://mjp.codeplex.com/releases/view/109905

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